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John P. Edwards
Oct. 1912

REPORT

OF THE

State Water Commission

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1912

OF

CALIFORNIA

1912

FRIEND WM. RICHARDSON, SUPERINTENDENT OF STATE PRINTING
SACRAMENTO, CALIFORNIA
1913

REPORT

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1912

REPORT OF THE STATE WATER COMMISSION OF CALIFORNIA.

SACRAMENTO, CALIFORNIA.

To his Excellency, the Governor, State of California.

SIR: In compliance with the provisions of Chapter 41, Statutes of 1911, creating and establishing this Commission, we have the honor to submit a report of the work performed from March 24 to November 1, 1912.

Respectfully submitted this first day of January, 1913.

STATE WATER COMMISSION,

CHARLES D. MARX, Chairman.

LOUIS R. GLAVIS, Secretary.

STATE WATER COMMISSION.

COMMISSIONERS.

HIRAM W. JOHNSON, *Governor*.....Sacramento, California.
CHARLES D. MARX, *Chairman*.....Palo Alto, California.
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HAROLD T. POWER.....East Auburn, California.
W. F. McCLURE.....Sacramento, California.
LOUIS R. GLAVIS, *Secretary*.....San Francisco, California.

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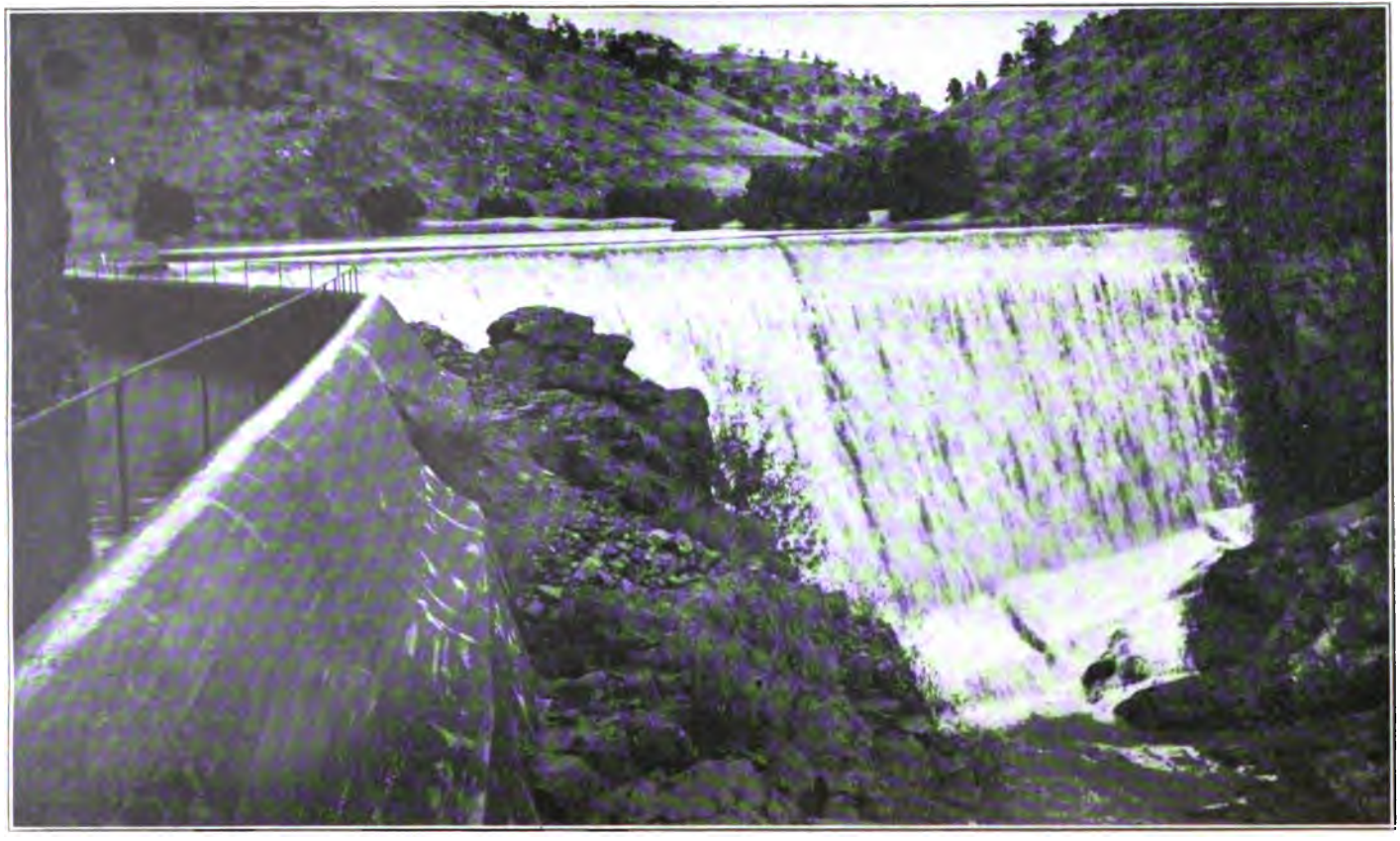


The La Grange dam on the Tuolumne River. This dam diverts water for the Modesto-Turlock Irrigation District.

REPORT

This Commission assumed its duties on March 24, 1912, having succeeded the State Board of Control, Water Power, created under the provisions of Chapter 406, Statutes of 1911. The State Board of Control, Water Power, was organized May 4, 1911, and since its records were delivered to us, we shall briefly outline the nature of the work performed by it during the nine months of its existence.

The applications received by the Board for permits to appropriate the public waters of the State for power purposes were as follows:

North Fork American River	2
Bishop Creek	2
Bull Creek	1
Butano Creek	1
Cache Creek	2
Coffee Creek	1
Cottonwood Creek	1
Coyote Creek	1
Fall River	1
Feather River	6
Merced River	1
Mountain Home Stream	1
North Cañon	1
North Eel River	1
Owens River	1
Peavine Ravine	1
San Joaquin River	1
Smith River	2
Taylor Creek	1
Trinity River	1
Truckee River	2
Ward Creek	1

The fees collected by the Board of Control, Water Power, and deposited with the Controller, amounted to $310.00. An appropriation of $50,000.00 was made for the purpose of carrying out the provisions of the act creating the Board of Control, Water Power. The sum of $37,083.79 still remained unexpended when the present Commission succeeded the Board of Control, which was in existence for nine months. The sum of $12,916.21 was therefore expended by the latter.

The Board of Control, Water Power, made a complete record of all water filings for power purposes on each and every stream in the State of California. Examinations by the engineers of the Board disclosed the fact that fully ninety per cent of the filings made in accordance with the old method of the location of water filings were not made in good faith, and that practically nothing whatever had been done by these water claimants towards the development of the streams on which they had filed.

Many of these speculative filings have been the cause of much litigation, because when attempt is made by *bona fide* claimants to

actually develop water power, they are compelled either to buy off the speculator or have his filing declared by the courts to be invalid. Judicial proceedings are expensive and naturally require much time before being finally determined, hence, in order to avoid delay, a person desiring to really make a power development usually purchases the mere water rights of the speculator. Since capitalists are loth to invest where they are immediately confronted with expensive litigation they become discouraged and indignant, so that the project is abandoned, and as a result the water not only continues to remain unused, but also the State's commercial progress is retarded and many are deprived of the employment and benefits that necessarily arise in the development of water power. Under the law creating this Commission speculative filings are impossible. Persons desiring the use of water for the generation of electricity or other power, must make application to this Commission setting forth the point where the water is to be diverted from the stream; the point where it is to be returned to the stream; the amount of water desired; the amount of water to be developed and the purpose for which it will be used. The Commission upon receipt of an application causes an investigation to be made to determine whether the applicant is in good faith; whether the greatest development of the stream can be secured by the diversion of the water at the point mentioned, and whether the issuance of a permit would tend to injure any existing vested water right. After such investigation is concluded, a public hearing is held where any one interested may appear for or against the allowance of the application. The witnesses who appear are sworn and their testimony taken. With this testimony and the civil engineer's report the Commission is in possession of sufficient data to decide whether or not the granting of a permit to the applicant will be to the best interests of the State.

Since March 24, 1912, to November 1, 1912, this Commission has received thirty-three applications for permits to appropriate the public waters of the State for power purposes. The following is a list of such applications:

American River	1
Big Creek	1
Big Pine	2
Big Sur River	2
Big Tujunga River	1
Bull Creek	1
Butano Creek	1
Coffee Creek	1
Coyote Creek	1
Deer Creek	1
Fall River	1
Feather River	2
Goodale Creek	1
Hamlin Creek	1
Little Rock Creek	1
Merced River	1
Mountain Home Stream	1
North Eel River	1
Rawson Creek	1
San Joaquin River	3

Silver Cañon Creek	1
Smith River	1
South Fork Smith River	1
Trinity River	1
Truckee River	1
Volcano Canyon	1
Weaver Lake	1
West Branch, North Fork, Yuba River	1
North Branch, West Branch of North Fork, Yuba River	1
Total	34

Of these applications seven have been canceled, either on account of the abandonment of the application by the person filing it, or because after careful and diligent consideration of the testimony introduced at the public hearing, it was deemed in the interest of the State that they be ordered canceled. Permits have issued for fourteen applications. The developments under the applications approved called for a total expenditure of $6,125,325.00 and the theoretical horsepower capable of development under these permits amounts to 132,648 horsepower. Of the applicants holding permits for the development of water power, one has already completed the construction of his plant and license has issued. Under the terms of such license the State will receive an annual revenue of ten cents for each theoretical horsepower capable of development under the works as constructed.

The federal law relating to the disposition of water power sites on the public domain has been proven totally inadequate. It provides for a permit to use the right of way for the occupancy of the public lands, and for the occupancy of certain National Reserves—a mere license—revocable at the discretion of the head of the federal department who granted it. The power of revocation without compensation has caused great alarm in the eyes of capital, and rightfully. The Government officials, favoring permits that contain the right of revocation by the Secretary of the Department, defend their position upon the ground that such powers of revocation would not be exercised without justification. The confidence that the power to revoke permits would not be abused by the head of the Department was dispelled by the action of a former Secretary of the Interior in calling upon the city of San Francisco (which had been granted a permit under the act for its municipal supply in the Hetch Hetchy), *to show cause why the permit should not be canceled.* This action was taken regardless of the fact that the city of San Francisco had complied with all the terms of the permits. The Department of Agriculture in administering National Forests offers no better encouragement to the person desiring to conserve and develop the waters. As a result, development has been very greatly retarded in the public land states.

For a number of years there have been pending before congress, bills concerning the occupation and use of certain portions of the public domain for water power purposes. It is universally admitted that the present legislation, consisting principally of the act of February 15, 1901, is entirely inadequate to satisfy the present popular sentiment,

to encourage persons and corporations engaged in the occupation of generating electric power, or to protect consumers in the various states, all of whom have the right to demand the immediate cessation of the present enormous waste.

The plant of the Original Milling and Mining Company, on the Merced River. This Commission has issued a license to the above company.

The legislation proposed on this subject has assumed various forms, according to the individual prejudice of the person from whom it emanated. The urgency of proper legislation is everywhere admitted and so far no bill has found sufficient support to be passed by congress. This Commission, in coöperation with the Conservation Commission, believing that certain matters of State interests and expediency have

not been given a full consideration in the federal water power bills introduced by congress, has arranged for a conference with the Secretary of the Interior to be held in Washington, D. C., on November 18th, for the purpose of presenting the conditions as they actually exist in this State, and the hardships that one is confronted with in the effort to develop our streams for power purposes.

A view of the San Joaquin River, just before it debouches from the foothills. Quite a few notices of water locations have been posted here, but no means of diversion have ever been constructed.

We believe that immediate action should be taken by this State to protect its interest in the waters of Lake Tahoe, and therefore recommend the institution of a suit against the State of Nevada in the United States Supreme Court for the purpose of having the waters of Lake Tahoe and the Truckee River duly apportioned in accordance with the decision of the *Kansas* vs. *Colorado* case. In addition to the bringing of this suit, we believe that complaint on behalf of the State should also be filed against the Truckee General Electric Company, to restrain it from storing the flood waters of the lake. The importance and necessity of instituting these suits cannot be too strongly emphasized in order that the rights of the State of California may be fully protected.

Under a coöperative agreement entered into with the United States Geological Survey, there has been prepared a complete digest of all available data concerning the flow of streams in this State. This information is contained in Water Supply Papers, Nos. 295, 296, 297, 298, 299, 300. Copies of these publications are available to the public, and may be secured upon application to the United States Geological Survey, Washington, D. C., or to this office.

WATER POWER POSSIBILITIES ON PIT RIVER.

The statement which follows as to water power possibilities on the Pit River, power development of the Feather River, and on storage reservoir sites in the Sacramento basin, has been prepared from information furnished by Mr. M. O. Leighton, Chief Hydrographer of the Geological Survey, and by other officials of the same department.

The purpose of this statement is to give in convenient form information concerning the power possibilities of Pit River, and to designate the sections thereof that are most valuable for power development. Certain power values based on known fall and determined water supply will be given. The only thing here attempted is to give to the reader the information necessary for preliminary location of final water-power studies.

It is desired that especial emphasis be placed on the last sentence of the foregoing paragraph. Experience has shown that statements of the kind here given are grossly misunderstood, even by those who are of good repute among hydraulic engineers. For the benefit of such the Commission wishes to give assurance, viz.: *first*, that this is not intended to be a final report on the water-power privileges of the region; *second*, that the examinations necessary to the final location and adoption of a single site on any of these streams would properly consume more time and money than has been expended on the entire survey here reported; *third*, that the final development of the Pit will certainly not follow in all respects the unit divisions here suggested; *fourth*, that it would not be strange if minute study and the use of ingenuity in location would produce much more power than is estimated at some of the locations here named, and, conversely, some of the locations here described and rated may be found under present conditions of market and hydraulic practice to be quite without merit; *fifth*, that a power site which to-day may be considered unworthy a moment's consideration may in the next generation prove to be a first-class project; *sixth*, no effort has been made to study the cost of development or the market, which, in the final valuation of any site, are as important as the physical facts here considered.

Pit River is the northernmost of the larger tributaries of the Sacramento. A part of its drainage basin lies in the state of Oregon. The upper portion of the drainage area lies in country that is geologically a part of the Great Basin, the average elevation of which exceeds 6,000 feet above sea level. The average rainfall over this part of the Pit basin is about 10 inches annually. Consequently the region is semi-arid, and in some years quite arid. The flow characteristics of Pit River along this portion of its basin are typical of those of desert country streams. As far down as Bieber, California, above which the drainage area is 4,040 square miles, the flow of the river becomes practically

negligible during August and September in all except very wet years. This run-off condition extends below Bieber to about the mouth of Fall River, where the Pit begins to cut through the Lassen Peak volcanic ridge which forms the southernmost portion of the Cascade Range and enters into the Sacramento Valley. Over the lower portion of the Pit basin the rainfall is 40 to 50 inches annually. The river is fed by many large springs, shows comparatively steady flow characteristics, and yields a relatively large amount of water during the minimum months of August and September. Fall River alone brings into the Pit a contribution of about 1,500 second-feet derived from springs within its

Pit River Falls.

basin, while Hat, Burney, Kosk and Montgomery creeks, McCloud River, and other lower tributaries, largely spring-fed, contribute materially to a steady regimen of flow.

From the foregoing it will be seen that for water-power purposes the Pit River basin must be considered in two quite distinct parts. The first is that portion occupying the Great Basin country, the contributions of which to the lower valley consist largely of flood waters and in which the summer flow is practically negligible. The following statement taken from the flow records at Bieber show clearly the small value of the stream in its uncontrolled state in the dry period:

Year.	Minimum flow. Second-feet.	Duration of minimum flow. Days.	Average flow in second-feet during—		
			July.	August.	September.
1904	10	1	83	33	1.65
1905	0.8	2	52	9.6	1.23
1906	21	20	222	51	23.6
1907	45	8	323	72	51.5
1908	4	8	70	12	4.6

It is clear from the foregoing that the Pit basin above the mouth of Fall River is a non-productive stream from the water-power standpoint, unless provision be made for the storage of flood waters. This point will be considered farther on.

The second portion consists of the basin lying below the mouth of Fall River. For water-power purposes it is proper to treat this as a separate basin, and to neglect, except under assumptions which will later be described, the fact that the drainage from the area above passes out through the Pit. This will reduce the productive drainage area to about 1,680 square miles, at the very crest of which there is an initial flow from springs of about 1,500 second-feet.

The storage possibilities in the Great Basin portion will first be considered.

Storage—The entire flow of Pit River at Bieber can be controlled by storage reservoirs of which there are five good sites in the basin at and above this point. These sites have been surveyed by the United States Reclamation Service in connection with its studies of irrigation possibilities in the Sacramento basin.

The first and largest is the Bieber or Big Valley site. (The map of the Big Valley site has been transferred to profile sheet number 8, being one of the maps attached to this report.) A 100-foot dam located in the canyon about 7 miles below Bieber would afford a storage capacity of 3,196,000 acre-feet, an amount considerably in excess of the annual flow of Pit River. It would, however, flood some desirable land within the reservoir site which is now irrigated in its lower portion by diversion canals from Pit River and from Ash Creek. The feasibility of such a project can be determined only after thorough consideration of the cost of construction and the damages by flooding. It will be shown farther on that only about one third of the capacity of the Big Valley site will be required to control the entire flow of the Pit above Bieber. Therefore, in determining the feasibility of this reservoir, it will be important to consider the relative economy of this partial development, as compared with that of other sites in the basin. The land within the basin is said to be valued at from ten dollars to thirty dollars per acre, according to the quality of the soil and the facilities for irrigation. It is principally valuable for hay fields and stock raising.

The second reservoir site is located in Round Valley on Ash Creek, a short distance above Adin in township 39 north, range 9 east, Mt. Diablo Meridian. A dam 70 feet in height would afford a storage

capacity of 184,700 acre-feet. Round Valley consists largely of meadow land in private ownership.

A third site is located in Warm Springs Valley (townships 41 and 42 north, ranges 10 and 11 east), with the dam site about 4 miles below Canby. A 70-foot dam would afford a storage capacity of 559,000 acre-feet. The entire site is in private ownership and is used for ranching purposes. The land is valued at from ten dollars to twenty dollars per acre.

A fourth site is situated in West Valley on the Lassen and Modoc county lines in township 39 north, range 14 east. A 70-foot dam located in a canyon at the mouth of the basin would afford a storage capacity of 94,600 acre-feet. The site consists of meadow land in private ownership.

The Jess Valley site, situated in township 39 north, ranges 14 and 15 east, is also in private ownership. A 60-foot dam located about 500 feet below the mouth of the basin would afford a storage capacity of 224,600 acre-feet.

Measurements of stream flow necessary to determine the most feasible storage plan are not yet available. Sufficient data have been collected at Bieber and Canby to determine the feasibility of the Big Valley and Warm Springs Valley sites, but the records that will be necessary to properly determine the relation of these sites to the other three above mentioned were started by the State Conservation Commission only about one year ago. The results are not yet of sufficient scope to make it possible to determine whether the development of these sites would reasonably compensate the low-water flow of Pit River without the development of the Big Valley or Warm Springs Valley reservoirs. Therefore, the present discussion will be wholly based on the fact that it is possible by the erection of the Big Valley reservoir to control the entire flow of Pit River above Bieber. Measurements of flow at this point are available from January 22, 1904, to September 30, 1908. This period includes a year of low water, though probably not as low as may occur in the future. Nevertheless the data can be used if a reasonable factor of safety is applied to the results. Attention is invited to the accompanying storage mass curve (Sheet Number 9) based on the recorded flow at Bieber.

A mass curve is merely a graphic representation of the discharge of a river by summation. The curve is begun by plotting the total flow for the first day, week, month, or any other suitable unit period. In the curve here discussed the month is the unit period. To the flow of the first month that of the second is added, and to the sum of these two the flow of the third, and so on throughout the entire record.

The Pit River curve shows that the total flow throughout the period above mentioned is approximately 3,570,000 acre-feet. The mass curve shows not only the total volume of water at any designated time, but also the relative rate at which the water was delivered from month to month, indicating clearly the periods of large and small flow. Accompanying this curve is a vector diagram showing the slope of the lines

corresponding to a discharge of from 1,000 to 2,000 second-feet. The vector diagram may be simply explained by saying that if the mass curve of any river were a straight line taking the direction of, say the 1,000 second-foot vector, then that river would have a uniform flow of 1,000 second-feet all the year round. The fact that the mass curve of Pit River is crooked shows that its flow is not uniform, being at times more, and at other times less than 1,000 second-feet.

Pit River, above falls.

To determine the amount of storage necessary to produce a given uniform flow, the mass curve serves better than any other form of expression yet devised. In the case of the Pit River curve the straight

line extending between the crests of the two largest "humps" is approximately parallel to the vector that represents a flow of 1,000 cubic feet per second. The testimony given is as follows: Starting at the crest of the first "hump," which corresponds to the month of May, 1904, the line again joins the curve at a point corresponding to the month of June, 1907. During the intervening period the flow of the river varied enormously, being at times in excess of 20,000 second-feet and at others less than 10 second-feet. What is the storage capacity that would have been necessary to maintain the flow in the river below the dam, at a rate represented by the vector that connects the crests of the two large humps on the mass curve? It is represented by the equivalent of the maximum ordinate running from the vector line to the curve, the position of which corresponds to that of December, 1905. By the ordinate scale the amount represented is about 825,000 acre-feet. This is the storage capacity that would, during the period of observation at Bieber, have enabled those in charge of the reservoir to maintain the flow below the dam at not less than a trifle in excess of 1,000 second-feet. As the available storage capacity at the Big Valley site is more than 3,000,000 acre-feet, it is apparent that only a small part thereof would require development in order to completely control the flow of Pit River below Bieber.

It will now be necessary to consider the net yield that may be produced by such a reservoir. It has already been stated that the period of observation used for constructing the mass curve does not embrace a year of extreme low water. This warrants a reduction in practical estimates of the amount indicated above as continuously available under storage. On the other hand, it should be recognized that the actual difference between the low waters in the years of record and that in an abnormally low year does not amount to much in the aggregate when compared with the large volumes that would actually be available for storage. Indeed, it might occur that it would not introduce any change in vector direction on the mass curve.

A compensating factor arises from the fact that there is considerable irrigation taking place during the low-water seasons within the basin of the proposed Big Valley reservoir. How much water is diverted from the stream is not known, but from the area of land irrigated it is easily determinable that it must be a considerable amount. A large part of this water is lost by absorption and evaporation. If the reservoir were constructed, the land would be overflowed and the irrigation would cease. Against this, however, is the evaporation loss that would take place from the reservoir surface. It is not known how much this would be, but it would probably be in excess of three vertical feet annually, an amount which markedly reduces the effective capacity of the reservoir. In view of recognized losses and the uncertainties concerning the amounts thereof, it will in subsequent estimates be conservatively assumed that the amount available from the reservoir throughout the year would be only 900 second-feet instead of 1,000 as indicated by the mass curve.

The amount of water available from that portion of the Pit basin below the proposed Big Valley reservoir will now be considered. No long-term records of flow are available, and it is necessary to make estimates based largely on certain short-term data and the excellent records on Sacramento River at Iron Canyon.

The marked difference between the run-off characteristics of the upper and lower portions of the Pit basin, previously described, make it unsafe to extend without confirmatory studies the daily run-off ratios based on Iron Canyon records up to the various power sites on the Pit between its mouth and Fall River. The only data available on the Pit

A view of the Pit River.

are one year's records at a point near Ydalpom about 3½ miles above the mouth of McCloud River and a few observations at Henderson. There are fairly adequate data on the McCloud, and these are of material assistance in determining the yield of the Pit. The natural conditions in the basin render it possible to make a very close estimate of the minimum flow. Practically all of the precipitation over the Pit basin occurs from November to April of each year. Therefore, during the months of July, August and September the records of Iron Canyon show a gradually diminishing flow. The discharge during such periods consists entirely of the water yielded from ground storage. There are few or no complications due to increase in flow on any of the tributaries occasioned by small rains, and the whole basin is in what might be called a state of drainage equilibrium. The relations between the

flow at Iron Canyon and at any other point above that place on the basin are quite uniform. This is borne out by a comparison of the records at Iron Canyon on the Sacramento, and at Gregory on the McCloud. It is possible to construct a reasonably accurate rating curve based on these two series of records. It naturally follows that a rating table may be constructed for the Pit near Ydalpom on the same basis using records secured at the two places during July, August and September, 1911. Examination of the records at these two places reported in Water Supply Paper 298 of the Geological Survey, prepared in coöperation with the State Conservation Commission and the State Water Commission, will show how steady is the flow of both rivers during those two months and how gradual is the decrease in flow. Pursuing the matter in this way, the following rating table has been derived:

Relative flow of Pit River near Ydalpom and Sacramento River at Iron Canyon, July, August, and September, 1911.

Sacramento River (second-feet).	Pit River (second-feet).
4,000	2,500
4,250	2,640
4,500	2,790
4,750	2,940
5,000	3,100
5,250	3,290
5,500	3,520
5,750	3,770
6,000	4,160

The lowest flow recorded on Sacramento River at Red Bluff occurred from September 7 to 28, 1903, and amounted to 3,980 cubic feet per second. The equivalent at Ydalpom according to the above rating is about 2,490 second-feet.

The only other record of assistance in properly extending the minimum flow relation up river from Ydalpom consists of two measurements made at the gaging station at Henderson on May 9 and August 12, 1911. The relations between the discharge at Ydalpom and Henderson on those two days are as follows:

	Ydalpom (second-feet).	Henderson (second-feet).
May 9	6,740	5,350
August 12	3,220	3,110

The flow relations of Henderson to Ydalpom on the two days are .8 and .9, respectively. Inasmuch as the relation of August 12th represents a condition of drainage equilibrium on the basin, coming as it does in the midst of a long dry period when the flow of the river was gradually subsiding, it is undoubtedly preferable for use in determining the minimum flow relation. Under this assumption the indicated minimum flow at Henderson would be 2,240 second-feet.

The effective drainage area above Ydalpom is 1,661 square miles. That above Henderson, or the mouth of Kosk Creek is 762 square miles. The intervening drainage area, 899 square miles was therefore produc-

tive of only 250 second-feet, or .28 second-feet per square mile. It is evident that the area above Henderson is far more productive than that below.

The distribution of flow above Henderson is very difficult of determination from the scanty information available. It is known that the Fall River springs furnish the greater part of this flow and that the yield of Fall River is approximately 1,500 second-feet. The only actual measurement of record was one made on September 9, 1901, near the mouth of the stream, the flow being 1,450 second-feet. This date is fortunately near the close of the dry season when the flow was at or near its minimum. A measurement made on September 2d of the same year at the old gaging station on Sacramento River at Jelly's Ferry, a short distance above the present Iron Canyon station, gives a discharge of 4,390 second-feet, which is close to the minimum observed at the latter point. It is safe to assume then that the year 1901 was one of low water in that region, and the gaging above noted on Fall River reasonably indicates the minimum at that point.

By subtracting from the indicated minimum flow at Henderson 2,240 second-feet, the probable minimum of Fall River 1,450 second-feet, there will remain 790 second-feet which may safely be considered as derived from the 762 square miles lying above Henderson. This is equivalent to about 1 second-foot per square mile.

On the above basis of estimate the water powers on the Pit will be rated as follows: Start at the head of the effective area with 1,450 second-feet, the contribution made by Fall River; from there to Henderson increase the flow by a factor of one second-foot per square mile; from Henderson to Ydalpom increase by a factor of .28 second-foot per square mile. This schedule, while unsatisfactory in some respects, probably does not do violence to reasonable probability and cannot fail to be much safer than the usual estimates based on rainfall records and remote and incomplete flow measurements.

POWER SITES.

The following power estimates are based on the theoretical power of a given amount of water, falling over a given height, the result reduced to 70 per cent to allow for mechanical and hydraulic losses in conduits, water motors and tailrace. This will give a result that will conservatively represent available power on the wheel shaft.

Big Valley dam site to the mouth of Fall River—This stretch of river is about 31 miles long. It has already been explained that because of very low flow during August, September, and in some years, through October and November, the river as far down as the mouth of Fall River is without value for primary power unless storage reservoirs are constructed. It has further been indicated that with the Big Valley reservoir constructed, a minimum flow of 900 second-feet may be assured. While it is probable that the drainage area between the reservoir site and the mouth of Fall River yields some water during dry seasons, the amount is very small and for primary power studies may safely be neglected. This stretch of the Pit will therefore be rated on the basis of 900 second-feet available from the Big Valley reservoir.

The stretch of river here discussed is naturally divided into four portions, two of which are of great slope and the remaining two of which are practically flat. The first section begins about one half mile below the dam site, corresponding approximately to Mile 118 on the accompanying profile. From there to about Mile 108, the fall is about 760 feet, or 76 feet per mile (as found on Sheets 7 and 8 of profile). The available power along this section, based on the factors and assumptions above given, is 54,720 horsepower.

The second section extends from Mile 108 to about Mile 100.5. (Sheet No. 7 of profile.) Along this stretch the stream meanders through a wide valley and the total fall is 33 feet or 4.4 feet per mile. This section will not be considered for power purposes except as described in the next paragraph.

The third section extends from Mile 100.5 to about Mile 99.5. (See Sheet 7.) The fall over this single mile of river channel is 62 feet and the available power is 4,460. It should be noted that it would be possible to increase the head at this site by the erection of a dam just above the head of this section where the broad valley noted in the previous paragraph narrows somewhat. A dam 40 feet high would be about 2,900 feet long and would overflow the entire valley above and reduce by about 7 feet the available fall in the first section above described. The increase of power afforded at the third section would be above 2,880 horsepower. Such a development is not seriously proposed because of many obvious reasons and difficulties. The possibility is merely noted because in some future time changed conditions of power market may render it worthy of consideration.

The fourth section from Mile 99.5 to the mouth of Fall River is practically flat and has no power importance. (See Sheets 7 and 6.)

The available power from Big Valley dam site to the mouth of Fall River is, under the assumption above made, 59,200 horsepower.

From the mouth of Fall River (about Mile 90) to Mile 80. (Sheet No. 6 accompanying this report.) Along this section there is a fall of 488 feet. The effective flow for primary power purposes, is assumed, as explained in a previous paragraph, to be the low-water flow of Fall River, *i. e.*, 1,450 second-feet. The available primary power is therefore 56,600 horsepower. With an additional flow of 900 second-feet available from Big Valley storage the primary power would be 91,700 horsepower.

In the actual development of power along this section, the total head might be increased considerably by the construction of a dam at or near the upper limit. Between Mile 91 and Mile 89.2 there are a large number of possible dam sites. A dam raised to say 3,300 feet above sea level would be less than 75 feet high and would afford an additional head of 55 feet. The broad flat valley above would be submerged, and also the power privilege at Mile 100. Whether it would be of hydraulic advantage to combine the two sites in this way, and whether the cost of the same and the damages from flowage would outweigh such advantages, is a matter for minute local study. A shortening of the headwater conduit by tunnel across the bend which has its heel at Mile 88 would probably be feasible and economical whether the diversion were made at grade or at dam elevation.

Section from Mile 80 to the mouth of Burney Creek (Mile 70.7). (Sheet No. 5 of profile.) This section has a relatively low slope, the total fall being 69 feet or about 7.5 feet per mile. Therefore, it does not offer as good power privileges as some other parts of the river. If the demand for power were sufficiently great, it might be practicable to utilize the entire fall along this section by erecting a dam in the head of the canyon at about Mile 70, flooding the valley above and thereby increasing the available head in the section next below.

Section from Burney Creek (Mile 70.7) to Rock Creek (Mile 66). (Sheet No. 5 of profile.) The fall along this section is 134 feet or about 28.5 feet per mile. By reason of the tortuous channel of the river a tunnel conduit would shorten the distance from diversion to power house to about 2¼ miles. As the channel lies in a steep canyon along the entire stretch it is probable that a tunnel would be as cheaply constructed as an open or pipe conduit following the river's course.

The effective drainage area above the mouth of Burney Creek, including that of said creek, is 649 square miles. On the assumption previously made, *i. e.*, a minimum flow of 1 second-foot per square mile, and a minimum flow of 1,450 second-feet from Fall River, the available flow for primary power development in this section is 2,099. This amount developed over a head of 134 feet would produce 22,500 horsepower. With Big Valley storage available the primary power would be 32,100 horsepower.

Section from Rock Creek (Mile 66) to Mile 62.5. (Sheets Nos. 5 and 4 of profile maps.) Along this 3½ mile stretch the fall is 143 feet. The drainage area above and including Rock Creek is 700 square miles. This indicates a probable minimum flow of 2,150 second-feet, equivalent to 24,600 horsepower. With Big Valley storage available, this would be increased to 34,900 horsepower.

Section from Mile 62.5 to Mile 54.6. (Sheet No. 4 of profile map.) This section lies entirely in canyon like the one above and has a fall of 340 feet. The effective drainage area above the head of the section is 720.4 square miles. The minimum flow without storage is 2,170 second-feet and with Big Valley storage would be 3,070 second-feet. The horsepower equivalents are 59,000 and 83,500, respectively.

Section from Mile 54.6 to mouth of Kosk Creek (Mile 47.2). (Sheets Nos. 4 and 3 of profile maps.) The effective drainage area above the head of the section is 734.5 square miles, and the total fall is 470 feet. The minimum flow is therefore 2,184 second-feet, equivalent to 82,100 horsepower. With Big Valley storage the power would be 116,000 horsepower.

Section from Kosk Creek (Mile 47.2) to Mile 40. (Sheet No. 3 of profile map.) Near the head of this section is the Henderson gaging station, below which, as noted on a previous page, the run-off per square mile factor is changed to .28. This section is 7.2 miles long and has a fall of 245 feet. The drainage area above Kosk Creek is 786 square miles. This creek drains 63.7 square miles. The minimum flow at the head of the section is therefore about 2,254 second-feet, which, over a 245-foot fall, is equivalent to 44,200 horsepower. Big Valley storage would increase this to 61,800 horsepower.

Section from Mile 40 to mouth of Montgomery Creek (Mile 31.7). (Profile sheets Nos. 3 and 2.) The fall in this section is 230 feet or about 28 feet per mile. The drainage area above the head of the section is 891.7 square miles which will yield a minimum flow of 2,270 second-feet. The equivalent horsepower is 41,800 and with Big Valley storage, 58,300.

Section between Montgomery Creek (Mile 31.7) and Mile 27.4. (Profile sheet No. 2.) This section includes the 891.7 square miles above the previous section, the 90.1 square miles between Mile 40 and the mouth of Montgomery Creek and the 47.4 square miles constituting the basin of said creek—in all 1,029.2 square miles. This is an increase of 137.5 square miles, the minimum flow of which is 38.5 second-feet. This amount added to the 2,270 second-feet available in the section next above gives a total of about 2,300 second-feet. The fall in the section is 101 feet or 23.5 feet per mile. The available primary power is therefore 18,600 horsepower, which would be increased by Big Valley storage to 25,900 horsepower.

Section between Mile 27.4 and Mile 20.5. (Profile sheet No. 2.) The effective drainage area above the head of this section is 1,049.9

square miles, and the minimum flow is 2,310 cubic feet per second. The total fall in this section is 120 feet, and the indicated primary power is 22,200 horsepower, which would be increased by Big Valley storage to 30,800 horsepower.

Section between Mile 20.5 and Mile 9. (Profile sheets Nos. 2 and 1.) The drainage area above the head of this section is 30.8 square miles greater than that of the next previous section. Therefore the minimum flow is increased by about 9 cubic feet per second or a total of 2,320. The fall in the section is 165 feet or 14.3 feet per mile. This will afford a primary power of 30,600, or with Big Valley storage, 42,500 horsepower.

Section from Mile 9 to mouth of McCloud River (Mile 4.6). (Profile sheet No. 1.) The drainage area above this section is 145 square miles greater than that above the previous section. Therefore, the minimum flow is increased by about 41 second-feet or a total of 2,341 second-feet. The fall in this section is 55 feet, or 12.5 feet per mile. This will afford a primary power of 10,300, or with Big Valley storage 14,300 horsepower.

In the 4.6 miles between McCloud River and the mouth of the Pit the fall of the river is 40 feet or less than 10 feet per mile. While the total available power is relatively large, this section of the stream does not appear to be well adapted to power development and will therefore not be considered in this report.

A summary of the foregoing paragraphs appears in the following table. This table does not include all the power facilities of the Pit basin. Some of the tributaries, notably the McCloud and Fall rivers, are extremely efficient power streams which at some time in the future should be surveyed and presented in the manner followed in this report.

There are also several reservoir sites not described in this report, the development of which would add materially to the primary power available in the main stream.

Table showing possible power development on the Pit.

Limits of section.	Sheet number.	Distance between points.	Fall between points.	Fall per mile.	Drainage area.*	Minimum discharge.		Available power 70 per cent efficiency.	
						Without storage.	With storage in Big Valley.	Without storage.	With storage.
		Miles.	Feet.	Feet.	Sq. mi.	Sec.-ft.	Sec.-ft.	Sec.-ft.	Sec.-ft.
Big Valley dam site (Mile 118) to Mile 108	8 & 7	10	760	76	----------	----------	900	----------	54,700
Mile 100.5 to Mile 99.5	7	1	62	62	----------	----------	900	----------	4,460
Mouth of Fall River (Mile 90) to Mile 80	6	10	488	48.8	----------	1,450	2,350	56,600	91,700
Burney Creek (Mile 70.7) to Rock Creek (Mile 66)	5	4.7	134	28.5	649	2,100	3,000	22,500	32,100
Rock Creek (Mile 66) to Mile 62.5	5 & 4	3.5	143	40.9	700	2,150	3,050	24,600	34,900
Mile 62.5 to Mile 54.6	4	7.9	340	43.+	720.4	2,170	3,070	59,000	83,500
Mile 54.6 to mouth Kosk Creek (Mile 47.2)	4 & 3	7.4	470	63.5	734.5	2,184	3,084	82,100	116,000
Kosk Creek (Mile 47.2) to Mile 40	3	7.2	245	34.+	849.7	2,254	3,154	44,200	61,800
Mile 40 to mouth Montgomery Creek (Mile 31.7)	3 & 2	8.3	230	28	891.7	2,270	3,170	41,800	58,300
Montgomery Creek (Mile 31.7) to Mile 27.4	2	4.3	101	23.5	1,029.2	2,300	3,200	18,600	25,900
Mile 27.4 to Mile 20.5	2 & 1	6.9	120	17.4	1,049.9	2,310	3,210	22,200	30,800
Mile 20.5 to Mile 9	2 & 1	11.5	165	14.3	1,080.7	2,320	3,220	30,600	42,500
Mile 9 to mouth McCloud River (Mile 4.6)	1	4.4	55	12.5	1,225.7	2,341	3,241	10,300	14,300
Total storage	----------	----------	----------	----------	----------	----------	----------	412,500	650,960

*Figures given are effective area without storage, i. e., below boundaries of Fall River basin.

FEATHER RIVER.

The plans and profiles made in this basin for the present report are confined to the Middle Fork of Feather River. A final report on the water-power possibilities must be postponed until sufficient records of stream flow can be accumulated. We have arranged to install automatic gages at favorable points along the streams. At present, the only available data are those secured at three stations. The first is on the Middle Fork near Cromberg, in the north ½, section 24, township 23 north, range 11 east. It has been maintained since November 3, 1910, as the result of coöperation between the Geological Service and the U. S. Forest Service. The gage is read occasionally when a Forest

The Middle Fork, Feather River.

Service official finds it possible to make a visit. Only two current-meter measurements have been made, one November 3, 1910, when the discharge was 54 second-feet, and another on October 28th, discharge, 89 second-feet. The data are not sufficient for any reasonable safe approximations of flow. The second station in the Middle Fork basin was located on Grizzly Creek near Beckwith, Cal. It was established December 17, 1905, and discontinued on September 30, 1906, because it was impossible to secure an observer. During this short period a maximum flow of 681 second-feet and a minimum flow of .2 second-feet were observed. These records are not sufficient for the determination of Grizzly Creek discharge, and are quite inadequate to show the discharge of the Middle Fork in the higher portions of the basin. The third station is located at Bidwell Bar near the mouth of Middle Fork, and has been maintained since October 7, 1911. Here, too, the period of observation is too short to permit of reliable estimates.

Although fairly satisfactory data have been secured on the North Fork, the figures cannot be applied to the Middle Fork because of the fact that the two basins differ geologically. By reason of the fact that the basin of the North Fork is so largely overlaid with lava, which

A view of Grizzly Creek near headwaters of Middle Fork, Feather River.

results in a comparatively steady run-off, and the occurrence of large springs, the run-off characteristics must be markedly different from those of the Middle Fork of Feather River, which is largely a granitic area. It is known in a general way that the yield of the Middle Fork is considerably less than that of the North Fork. Neither is it possible to apply the run-off data of Yuba River which lies south of the basin of the Middle Fork. The only record in the Yuba basin extending over

a period of years sufficient to permit of reliable estimates is that at Smartsville in the foothills. The stations in the upper portions of the Yuba have not been maintained for a period sufficiently long to permit of any estimates. With the Yuba basin data as a guide, an approximate estimate of the flow of Middle Fork might be derived, but the degree of accuracy would be problematical and the variation of the estimates from the truth might be as much as 500 per cent. Therefore, it is

A view of the Feather River just below Oroville.

believed wise to defer any water-power estimates for this stream until flow records have been secured.

In lieu of the report on the power possibilities of the Middle Fork the following statements are submitted concerning the developed and undeveloped power on the North Fork of Feather River. The state-

ments are taken from a report written by E. C. Murphy, hydraulic engineer, U. S. Geological Survey.

The basin of Feather River above Oroville, Cal., is 3,640 square miles in extent. The country is mountainous throughout, with deep narrow canyons interspersed here and there by meadows. It is heavily covered with commercial timber in the higher parts and with a thin growth of scrubby timber in the lower portion.

The main stream is formed 27 miles above Oroville where the Middle and North forks join. The former has a drainage area of 1,340, and the latter, 2,220 square miles. The unit run-off of the former is considerably less than that of the latter.

North Fork basin is naturally divided into several smaller ones, two of these known as the Eastern and Western basins, lying above Prattville. The Eastern basin has an area of 230 square miles and is drained by the Hamilton Branch, while the Western, having a drainage area of 245 square miles, is drained by the North Fork. These two streams join about 3 miles below Prattville at the lower end of Big Meadows.

North Fork of Feather River above Yellow Creek and Belden Station on the Western Pacific Railway.

About 7 miles below Prattville, Butt Creek joins the North Fork from the west. This stream drains an area of 74 square miles. Eight miles below Butt Creek, the East Branch, the basin of which is 1,020 square miles in extent, joins from the east. Two miles farther down, Yellow Creek enters the North Fork, while West Branch joins near Las Plumas about 9 miles above the mouth of Middle Fork.

In the southern part of the Feather River basin, the formation is mainly of granite with a good covering of soil; in the northern part the formation is mainly porous lava with a covering of soil which

rapidly absorbs water. The result is that ground storage in the North Fork basin is abundant and several of the tributary streams are formed by large springs, one of which has a minimum flow of 70 second-feet.

Flow records of Feather River have been maintained at Oroville during the period 1902 to 1911. The records of daily stage and discharge appear in Water-Supply Paper 298. The year 1908 is the lowest of record in the series, and the discharge for this year will be given farther on.

A station was located by the Great Western Power Company near the head of Big Bend tunnel, about 20 miles above Oroville, and the records are available for five and one half years. The mean monthly and annual results are given in the following table:

Monthly discharge of North Fork Feather River at Big Bend, California.
(In hundred second-feet.)

Drainage area.....1,940 square miles.

Month.	1906.	1907.	1908.	1909.	1910.	1911.	Mean.	Per cent annual.
January	64.9	35.1	37.7	.....	29.9	28.6	39.6	7.3
February	51.5	129.0	29.9	.....	35.6	37.1	56.6	10.6
March	96.8	183.0	45.9	.....	90.0	59.1	94.6	17.6
April	99.1	138.0	56.6	.....	70.0	154.9	105.7	19.7
May	94.3	93.3	51.3	.....	40.0	127.2	81.2	15.1
June	75.7	62.5	37.0	.....	15.8	86.9	55.6	10.4
July	29.2	27.0	15.9	18.2	11.6	21.8	20.6	3.9
August	15.4	17.2	10.1	12.9	9.7	17.4	13.8	2.5
September	13.1	14.7	9.9	12.0	10.0	12.9	12.1	2.3
October	12.4	15.2	11.9	14.8	10.1	11.9	12.7	2.4
November	16.1	15.8	13.1	32.3	12.8	12.6	17.1	3.2
December	40.7	29.8	13.0	36.2	22.4	10.6	27.1	5.0
Mean	50.8	63.4	27.7	.....	29.8	48.4	44.8	.....

Although the mean annual flow was lower in 1908 than in any other year, the discharge being 2,770 second-feet, the lowest mean monthly flow was in August, 1910, when the mean discharge dropped to 970 second-feet. On the 15th of this month, the flow was less than 800 second-feet.

A third station, also maintained by the Great Western Power Company, is located at the dam site of the Big Meadows reservoir below the mouth of Hamilton Branch. The average monthly flow at this station for the five and one half years of record is given in the following table:

Monthly discharge North Fork Feather River below Prattville, California.

Drainage area 506 square miles.

Month.	1905.	1906.	1907.	1908.	1909.	1910.	Mean.	Per cent annual.
January		937	814	917	2,550	844	1,212	8.0
February		1,210	2,300	809	1,310	908	1,317	8.7
March		1,590	2,800	1,140	1,380	2,160	1,814	11.9
April		2,210	3,290	1,500	2,120	1,780	2,180	14.4
May		2,770	3,230	1,500	2,580	1,250	2,266	14.9
June		2,190	2,650	1,110	1,950	768	1,734	11.4
July	761	1,200	1,280	723	1,010	662	939	6.2
August	670	795	951	635	800	602	742	4.9
September	644	688	826	610	734	623	688	4.6
October	631	769	794	632	731	625	682	4.5
November	628	698	758	647	1,200	697	771	5.0
December	607	894	939	612	1,010	908	828	5.5
Mean		1,320	1,720	903	1,450	987	1,264	

The minimum monthly flow of the North Fork at the station above mentioned occurred in August, 1910, when the average discharge was 602 second-feet, equivalent to a total monthly run-off of 37,000 acre-feet. The mean rate of flow for the entire period was 1,264 second-feet, equivalent to an annual run-off of 915,100 acre-feet. The year of least flow is 1908 when the total run-off was 653,800 acre-feet.

A fourth station also maintained by the Great Western Power Company is located on Butt Creek in Butte Valley about 2 miles above the mouth. The monthly record for the five and one half years of observation period is given in the following table:

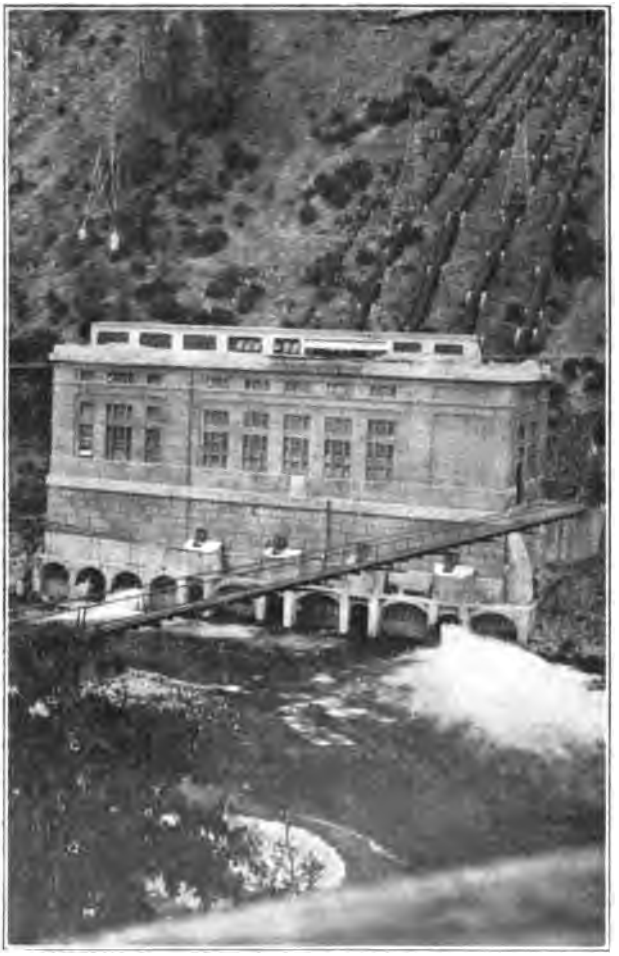
Monthly discharge of Butt Creek, Butte Valley, California.

Drainage area 73 square miles.

Month.	1905.	1906.	1907.	1908.	1909.	1910.	Mean.	Per cent annual.
January		221	95	77	460	66	184	12.5
February		141	312	63	178	73	153	10.5
March		287	367	113	159	221	229	15.6
April		360	500	173	280	165	296	20.1
May		320	343	132	233	65	219	14.9
June		220	186	65	104	31	121	8.2
July	47	69	67	30	41	26	47	3.3
August	34	46	44	25	33	26	35	2.4
September	32	45	40	27	32	26	33	2.2
October	32	43	38	27	42	26	35	2.4
November	33	49	42	28	84	35	45	3.1
December	59	90	98	30	91	53	70	4.8
Mean		158	178	66	145	68	122	

The average run-off per square mile of Butt Creek is about 24 per cent less than that of North Fork, and the minimum is 50 per cent less. The mean annual flow is 122 second-feet, equivalent to 88,300 acre-feet. In the lowest year of record, 1908, the total discharge was 47,800 acre-feet.

The flow of Yellow Creek has not been measured. It has been assumed that its annual run-off per square mile is about the same as that from



The Great Western Power Company's Plant, at Big Bend, on the Feather River.

Butt Creek, or 1.76 second-feet. As the basin has an area of about 80 square miles, the mean rate of flow would be, on this assumption, 133.6 second-feet, equivalent to 96,700 acre-feet.

Indian Creek has been measured for four years at a point near Crescent Mills, about 5 miles above the mouth of Spanish Creek. The results appear in the following table:

Monthly discharge Indian Creek (East Branch) near Crescent Mills, California.

Drainage area.....740 square miles.[1]

Month.	1906.	1907.	1908.	1909.	Mean.	Per cent annual.
January	870	500	480	2,910	1,190	11.0
February	820	2,210	360	1,380	1,192	11.0
March	2,000	2,930	990	1,200	1,780	16.5
April	2,550	3,860	1,030	2,540	2,495	23.0
May	1,790	2,110	660	2,020	1,645	15.2
June	1,010	1,000	310	960	1,570	14.5
July	230	240	70	240	195	1.8
August	53	91	15	35	49	.4
September	58	89	23	37	52	.5
October	95	114	59	101	92	.9
November	132	139	94	356	180	1.7
December	534	384	124	484	381	3.5
Mean	850	1,140	350	1,020	902	

[1]Total area drained by this stream, 1,025 square miles.

The run-off per square mile of Indian Creek is only about one half as large as that of North Fork at Prattville. Its maximum monthly rate is, however, nearly twice as large while the minimum is less than one tenth of that of North Fork. The record shows that the minimum monthly flow was 15 second-feet which occurred in August, 1908, which is equivalent to a total run-off for this month of 938 acre-feet. The mean annual run-off was 653,000 acre-feet and the minimum 253,400.

No flow measurements are available on Spanish Creek. The drainage area is about 175 square miles and has a lower elevation than that of Indian Creek, and therefore its run-off is somewhat less. If the mean rate be assumed to be 80 per cent of that of Indian Creek, the mean annual flow must be about 171 second-feet, equivalent to 123,800 acre-feet. A gaging made on August 14, 1912, showed the flow of this stream to be 28 second-feet. In the following discussion the minimum monthly flow of East Branch from the mouth of Spanish Creek to the North Fork has been taken as the sum of the rates of the flow of Indian Creek at Crescent Mills and Spanish Creek at Keddie, and is equivalent to 35 second-feet.

Flow records in Feather River basin cover relatively short periods of time. It is, therefore, probable that the minimum flow may have occurred before measurements began. If this is true the correct mean flow in the basin is less than that indicated by the existing records. It will therefore be of advantage to examine the measurements of precipitation in the basin, which cover a much longer period than those of

stream flow. Such an examination may make it possible to estimate in a relative way what was the probable minimum flow during the period not covered by the flow records. Four places have been selected in the Feather River basin where precipitation has been observed, namely, Oroville, Quincy, Greenville, and La Porte.

Mouth of Yellow Creek, showing flow to be developed by Oro Light and Power Company.

The following table gives the elevation, length of record, annual and average precipitation for the period of record, the mean for the period 1906–1911, the mean for 1906–1909, and the record for 1898 at these four places. The data are obtained from the records of the United States Weather Bureau.

Precipitation in Feather River Basin.

	Elevation.	Length of record.	Precipitation normal.	Precipitation.						Mean precipitation.		
				1906.	1907.	1908	1909.	1910.	1911.	1906-1911.	1906-1909.	1898.
Oroville	250	25	28.41	42.37	31.33	18.83	41.48	12.22	29.14	29.23	33.50	13.78
Quincy	3,400	14	48.41	66.92	67.10	32.37	68.87	23.65	46.95	50.99	58.84	24.28
Greenville	3,600	15	44.04	66.45	60.73	25.77	63.50	28.59	54.53	49.93	54.11	21.08
La Porte	5,000	13	89.17	124.46	113.94	58.08	141.40	60.22	----------	99.62	109.47	40.87

year 1908 at each of the five gaging stations is given in the following table:

Monthly discharge of streams in Feather River basin, 1908.

Month.	3640 sq. mi. Feather at Oroville.	1940 sq. mi. North Fork Feather at Big Bend.	506 sq. mi. North Fork Feather at Prattville.	73 sq. mi. Butt Creek at Butte Valley.	Indian Creek at Crescent Mills.
January	6,610	3,770	814	77	478
February	6,380	2,990	2,300	63	363
March	7,250	4,590	2,800	113	989
April	9,210	5,660	3,290	173	1,030
May	8,170	5,130	3,230	132	661
June	5,310	3,700	2,650	64	306
July	2,320	1,590	1,280	30	72
August	1,510	1,010	951	25	15
September	1,250	987	826	27	23
October	1,650	1,190	794	27	59
November	1,750	1,310	758	28	94
December	1,910	1,300	939	30	124
Year.					
Second-feet	4,400	2,700	1,720	66	351
Acre-feet	3,215,000	2,005,000	1,245,000	47,800	254,100
Drainage	3,640	1,940	506	73	740

On the foregoing assumptions the stored water in the reservoirs at the beginning of 1908 would have been as follows:

Big Meadows reservoir, 457,600 acre-feet, equivalent to a continuous flow of 632 second-feet.

Butt Creek, 44,900 acre-feet, equivalent to a continuous flow of 62 second-feet.

Yellow Creek reservoir, 95,200 acre-feet, equivalent to continuous flow of 66.8 second-feet.

Indian Creek reservoir, 326,500 acre-feet, equivalent to a continuous flow of 451 second-feet.

It has been estimated that all the water in storage at the beginning of 1908, less losses assumed to be 10 per cent, could have been used during that year without a shortage during the next year. It happens that the year 1909 was one of more copious precipitation than that of 1907. With all this storage available at the beginning of 1908 plus the natural flow during the year, the minimum monthly flow below each reservoir would have been as follows:

Big Meadows reservoir, 1,472 second-feet instead of 610 second-feet.

Butt Creek reservoir, 122 second-feet, instead of 25 second-feet.

Indian Creek reservoir, 756 second-feet, instead of 15 second-feet.

The minimum monthly flow of East Branch with storage may be taken to be 775 second-feet, without storage it is about 30 second-feet. The minimum monthly flow of North Fork from East Branch to Yellow Creek may be taken to be 2,370 second-feet with storage and 665 without storage. Below the mouth of Yellow Creek the minimum flow with storage would be about 2,500 second-feet, without storage 700 second-feet.

At Big Bend the minimum flow with storage would have been about 2,800 second-feet; without storage it was 990 second-feet.

It should be remembered that these figures, though applicable to the year of lowest stream flow of record, are based on the assumption that 50 per cent of the mean annual flow at the reservoirs was in storage at the beginning of 1908, and also that dry periods of longer duration and greater intensity than that of record have occurred.

Stream slope—The elevation of places along North Fork given in the following table were obtained from the topographic sheets and are only approximations. The distance between places are scaled from maps. The power houses and dams mentioned in this table belong to the Great Western Power Company and are described later. Project No. 1 is completed, and preliminary work has been commenced on Nos. 2 and 3. The location of power houses Nos. 2 and 3 and dams Nos. 2 and 3, and also the height of these dams, are subject to change:

Slope of Feather River, North Fork, East Branch, and Spanish Creek.

Locality.	Distance between places. Miles.	Low water elevation.	Fall in feet.
Oroville	0	150	
1.5 miles below Middle Fork	6	200	50
Power House Project No. 1	11	535	335
Dam Project No. 1	12	905	370
Power House Project No. 2	2	960	55
Dam Project No. 2	4.5	1,250	290
Power House Project No. 3	4.8	1,470	220
Dam Project No. 3	11.7	2,000	530
East Branch	5.0	2,260	260
Totals	57		2,110
Mouth Spanish Creek	*16.5	2,900	640
Railroad Bridge near Keddie	*2.5	3,045	145

*Distance by railroad.

In the 57 miles from the mouth of the East Branch to Oroville there is a total fall of 2,110 feet, equivalent to an average of 37 feet per mile. In the 40 miles from the East Branch to the power house of Project No. 1, there is a fall of 1,725 feet, or an average of 43.1 feet per mile. The average fall of East Branch from the mouth of Spanish Creek to North Fork is 40 feet per mile.

Available power—From the data on stream slope and minimum flow, the available power with and without storage can readily be computed. The minimum flow used is the average monthly flow in August, 1910, and the horsepower is computed from the equation—Power equals Fall in feet multiplied by Discharge in second-feet, divided by 11.

Minimum Power Available Monthly.

Locality.	Distance between places. Miles.	Total fall. Feet.	Without storage.		With storage.	
			Flow sec.-ft.	Power horse-power.	Flow sec.-ft.	Power horse-power.
From—To—						
Oroville to Middle Fork	7.5	110	1,170	11,700	3,000	30,000
Middle Fork to Power House Project No. 1	9.5	275	970	24,250	2,800	70,000
Power House Project No. 1 to Yellow Creek	38.8	1,675	†835	127,100	2,650	403,500
Yellow Creek to East Branch	1.2	50	665	3,020	2,370	10,770
East Branch to Spanish Creek	*16.5	640	30	1,750	775	45,100
Spanish Creek to Keddie	2.5	145	15	2,180	----------	2,180
Totals	76.0	2,895	----------	170,000	----------	561,550

*Distance by railroad.
†Average of flow at ends of part of stream considered.

From the foregoing it is seen that the portion of the river under consideration affords 170,000 gross horsepower without storage and 561,550 gross horsepower with storage.

North Fork Feather River, immediately above the dam site of the Great Western Power Company.

Feather River Project No. 1 at Big Bend belongs to the Great Western Power Company. It was begun in the fall of 1906 and the first power unit was placed in operation in December, 1908. A tunnel 3 miles in length across the river bend and a timber dam gave an initial head of 420 feet. In 1910, a concrete dam was built a short distance below the original timber dam which increased the head to 442 feet. A detailed description of this power plant is published in the *Journal of Electricity, Power and Gas*, volume 24, page 315. The power house of this plant is now being enlarged by the addition of two 18,000 horsepower Francis turbines, and the head available at the plant is being increased 10 feet by the placing of flash boards on the dam.

The dam of the Big Meadows reservoir now under construction is expected to be completed in 1913. That on Butt Creek is also being constructed. Investigations are being made in the Yellow Creek basin for the construction of that reservoir by the Oro Electric Corporation.

Applications for permits for water-power sites have been made to the Forest Service for four additional power projects on North Fork of Feather River. The location of these projects, together with that of the Big Bend, the Butt Creek, and the Yellow Creek projects, are shown on appended map.

The facts concerning the Great Western Power Company's Project No. 1 or the Big Bend project have been given. Project No. 2 has its head works located in section 6, township 22 north, range 5 east. The diversion dam is projected to 34 feet above low water and the headwater is to be conducted by tunnel down the right bank of the river to a point in the northern part of section 25, township 22 north, range 4 east. The static head on the wheels of this project will be 330 feet. Project No. 3 of the Great Western Power Company is located on the right bank of the North Fork in townships 24 north, range 6 east, and

Some of the San Joaquin River watershed, showing rough country.

23 north, range 5 east. The head works are located in sections 10 and 11 of the township first named. The dam will be raised 32 feet above low water to create a pondage area of 76 acres. The water will be conducted principally by tunnel conduit to a point in section 15 of the township last above named and the static head on the power house is 530 feet.

It appears from the foregoing that the heads on the power house of projects Nos. 1, 2, and 3 will be 1,333 feet under the assumption that the height of the dam of Project No. 1 will be increased 40 feet and that the friction loss of head in that project will be 13 feet. It

has been indicated that the fall from the mouth of East Branch to Oroville is 2,110 feet and that from East Branch to the power house of Project No. 1 is 1,725 feet. Thus only 433 feet of the fall from East branch to Oroville, or 20 per cent, is utilized, and in projects Nos. 2 and 3, 860 feet additional, or 41 per cent, are to be utilized. Of the 1,725 feet fall from East Branch to the power house No. 1, 25 per cent is utilized in project No. 1, and about 50 per cent additional will be used in projects Nos. 2 and 3. Thus about 25 per cent of the fall in

The Hetch Hetchy Valley, San Francisco's proposed storage reservoir.

the 40 miles from the East Branch to power house No. 1 is neither utilized nor applied for.

It is the apparent intention of the Great Western Power Company to use every foot possible of the fall in the river between Big Meadows reservoir and the power house of Project No. 1.

Projects Nos. 4 and 5 are located on North Fork above East Branch,

It is the intention to use the water in these reservoirs only when the and can be operated only when water is furnished from these reservoirs. flow of the East Branch and other uncontrolled streams will not furnish all the water needed for projects Nos. 1, 2, and 3. Thus it may occur that projects Nos. 4 and 5 will be operated only a few months of each year. Project No. 4 is located on the left bank of the North Fork with head works just below the junction of Butt Creek and the North Fork. The water will be conducted by tunnel to a power house located at the junction of East Branch with North Fork. Project No. 5 consists of a tunnel conduit along the right bank of North Fork leading from the Big Meadows reservoir dam to a point just above the head works of Project No. 4.

The project of the Oro Electric Corporation on Yellow Creek consists of a conduit leading from the proposed reservoir on that creek to a point on North Fork just above the mouth of Yellow Creek.

AMERICAN AND TUOLUMNE RIVER BASINS.

With this report are presented plans and profile surveys of the North, Middle, and South forks of American River and of Tuolumne River. Because of the lack of adequate stream-flow data, no report on power resources can be presented. The gaging stations now being maintained in these basins will, however, within a few years afford all the data necessary.

Float and guide for automatic steam gauge on Tuolumne River, just below South Fork junction. A scale gauge here read once a week for Yosemite Power Co.

SAN JOAQUIN RIVER.

This Commission, at the request of the State Engineer, has entered into a coöperative agreement with the United States Geological Survey for the purpose of making profile measurements and securing such other data as the appropriation will make available, of the San Joaquin River. This work is now being pushed rapidly to completion and will be completed by January 1st. As soon as maps and data are available a supplemental report will be made containing this information.

A leak in the Baldwin Creek syphon of the North California Power Company.

The maps of the profile surveys of the streams referred to accompany this report and are as follows:

Pit River, sheets 1 to 8.
Storage mass curve, Pit River at Big Valley reservoir site, sheet 9.
American River, North Fork, sheets 10 to 22.
Feather River, Middle Fork, sheets 23 to 26.
Tuolumne River, sheets 27 to 32.

STORAGE RESERVOIR SITES IN SACRAMENTO BASIN.

The United States Geological Survey has furnished us with statements of the principal facts relative to storage reservoir sites both available and utilized in the Sacramento basin. These data have been collected in past years principally by the United States Geological Survey and the Reclamation Service. More extended discussions of the storage possibilities on Cache Creek and Stony Brook appear in Water-Supply Papers Nos. 45 and 86, respectively.

PUTAH CREEK.

Putah Creek is the most southerly of the Coast Range streams draining into the Sacramento Valley. This valley was explored by Hubert E. Green, engineer, in July, 1903, for possible reservoir sites. Three sites were discovered.

Guenoc Reservoir—The Guenoc site was the most promising of these, and was surveyed in July and August, 1903. This site is situated in Lake County, in township 11 north, ranges 6 and 7 west, Mt. Diablo Base and Meridian. Guenoc Valley, also known as Coyote Valley, lies in a basin near the headwaters of Putah Creek about 40 miles above the foothills of the southwestern part of the Sacramento Valley. The drainage area above the Guenoc site is about 148 square miles. This watershed is located in the Coast Range, and has several high peaks in the neighborhood, such as Mount St. Helena, Pine, Geyser, Childers, and Round Valley peaks. The elevation of Mount St. Helena is 4,743 feet.

Estimates of cost for the development of this reservoir were made in 1900 by the U. S. Reclamation Service based upon a 100-foot dam with spillway at 90-foot elevation. Such a dam would impound about 145,000 acre-feet. If the dam were raised 10 feet higher, the storage would be increased 45,000 acre-feet. Such a reservoir could be usefully operated to regulate the flood discharge in the Yolo basin.

The dam site is located at the end of a very flat valley of some 3,000 acres. The stream at this point makes a sharp bend and flows for some distance a little west of north, so that the axis of the proposed dam lies in direction north, 70 degrees east. The channel is filled with large boulders and the sides of the canyon have a slope of about 1½ to 1. They are covered with small pines, mountain oaks, together with more or less scrub vegetation. Superficial examination indicates a depth to solid rock of from 4 to 5 feet on the side walls. To rock at the bottom of the stream is estimated to be about 20 feet below the channel bottom.

A natural spillway is afforded for the reservoir about 1 mile southeast of the dam site where a rocky gap divides this valley from an adjacent smaller one. The latter is a marshy lake of some 45 acres area, into which flood waters could be safely discharged, running from this lake back to Putah Creek about 2 miles below the dam site. The length of the proposed spillway would be 740 feet, and with 5 feet over the sill it would be capable of discharging 27,500 acre-feet.

Specifications for a rubble concrete dam made in 1900 are as follows:

Length of dam on crest	450 feet
Width of crest	15 feet
Maximum height	120 feet
Elevation at base of dam	1,070 feet
Elevation at outlet of dam	1,120 feet
Elevation at lip of spillway	1,180 feet
Elevation at crest of dam	1,190 feet
Water slope	5 in 100
Lower slope	75 in 100
Capacity of reservoir	143,300 acre-feet
Weight of rock per cubic feet	167.5 pounds
Total amount of concrete	33,532 cubic yards
Additional rock	11,178 cubic yards
Rock excavation at dam	8,500 cubic yards
Earth excavation at dam	2,000 cubic yards
Rock excavation at spillway	4,000 cubic yards

The estimated cost of this reservoir in 1900 was about $550,000, which should be largely increased to keep pace with increased cost of materials and labor that prevails to-day.

MONTICELLO RESERVOIR SITE.

The Monticello reservoir site is located in Napa County, in township 8 north, ranges 2 and 3 west, Mt. Diablo Meridian, and in Las Putas land grant, and extends westerly from the boundary line between Napa and Yolo counties to a point 1 mile west of the town of Monticello. The dam site is located on Putah Creek at a narrow gorge about 10 or 12 miles west of Winters. Bedrock is exposed on both sides of the canyon, and is apparently not far below the surface of the stream, and is composed of heavy gray sandstone. The stone is being quarried at the dam site and used for building purposes. The weight per cubic foot determined from sample taken from the quarry is 173 pounds.

Because of the large area of improved farming land in Berryessa Valley that would be flooded by back water from the overflow weir or dam during high water, if the elevation of the weir should be fixed at 150 feet, it is believed that the top of the weir should be at the 140-foot contour. The effective storage capacity of the reservoir at this elevation is 99,000 acre-feet. This height has been taken in making the estimate. The elevation of the top of the dam has been fixed at the survey contour of 155 feet, and the wasteways at 140 feet, which is about 130 feet above the stream. The wasteway on the right bank is 100 feet and the one on the left bank 125 feet wide. These will be formed by excavating rock on either side of the canyon for the construction of the dam. With the water at the top of the dam or 15 feet on the weirs approximately 43,000 second-feet would be discharged; with 2 feet of water over the dam approximately 55,000 second-feet would be discharged; and with 5 feet of water over the dam approximately 78,000 second-feet would be discharged. The maximum flood flow of Putah Creek at Winters, on March 23, 1907, was estimated by the Geological Survey at 33,000 second-feet. If the run-off should reach 100 feet per square mile, the maximum discharge would be 51,500 second-feet. The capacity of the reservoir at the 140-foot elevation is approximately 99,400 acre-feet, and at the 150-foot elevation 130,000 acre-feet.

Capacity of Reservoir Site.

Height above bottom. Feet.	Area. Acres.	Capacity between contours. Acre-feet.	Total capacity. Acre-feet.
20	25.1		
		386.0	
Outlet 30	52.1		386.0
		802.0	
40	108.3		1,188.0
		1,196.5	
50	131.0		2,384.5
		2,000.0	
60	269.0		4,384.5
		3,170.5	
70	365.1		7,555.0
		4,346.0	
80	504.1		11,901.0
		5,841.5	
90	664.0		17,742.5
		7,908.0	
100	917.4		25,650.5
		11,004.5	
110	1,283.5		36,655.0
		15,755.0	
120	1,867.5		52,410.0
		21,163.0	
130	2,365.1		73,573.0
		25,822.0	
140	2,799.3		99,395.0
		30,610.0	
150	3,322.7		130,005.0
Total			130,005.0

Capacity at 140 contour..... 99,395 acre-feet.
Capacity below 30 contour..... 386 acre-feet.

99,009 acre-feet.

Average storage capacity, 99,009 acre-feet. Drainage area, exclusive of that above Guenoc site, 455 square miles. Elevation of outlet, 30 feet. The mean annual run-off for the four years, 1906-09, was 601,000 acre-feet.

If the works should be constructed as designed it might be desirable to increase the height of the weirs to 150-foot elevation at some future time, if the demand for irrigation water should justify it. No soundings have been made for bedrock at the dam site. It has been assumed that it will be reached within 30 feet below the present river bed, which is approximately 10 feet in elevation. A rubble concrete overflow dam has been estimated upon. It has been assumed that 70 per cent of the mass of the dam will be large rock (quarried from the spillways), 15 per cent cement mortar, and 15 per cent concrete. There is a large amount of sand and gravel in the stream bed a few hundred feet above the dam site, which can be used for making concrete. In addition to the stability of the dam on account of its weight, it is proposed to construct this as a curved dam with a radius of 320 feet on the upper face.

A portion of land that would be flooded by the construction of this reservoir is in bearing fruit trees with substantial farm houses. Practically all of the town of Monticello would be submerged, a large stone bridge across Putah Creek and a small stone bridge over tributary of Putah Creek near Monticello would be under water, and the lower part of Berryessa Valley.

Specifications.—Curved overflow rubble masonry dam, with spillway.

Elevation of top of dam	155 feet
Elevation of spillways	140 feet
Assumed elevation of bed rock	20 feet
Elevation of outlet	30 feet
Maximum height of dam	175 feet
Capacity of reservoir	99,000 acre-feet
Capacity of 3 outlet gates under 10-foot head	942 second-feet
Capacity when water is 15 feet deep on spillway	3,360 second-feet
Weight of rock per cubic foot is	173 pounds

It has been assumed that 70 per cent of the dam is to be large sandstone blocks, 15 per cent cement mortar, and 15 per cent concrete.

Estimate by Reclamation Service of cost of dam, outlet works, right of way, engineering, contingencies, supervision, and contractor's profits $1,219,075

This is equivalent to a cost of storage works per acre-foot of water of $12.31, which should be largely increased on account of present prices of materials and labor.

CACHE CREEK, CALIFORNIA.

LOCATION AND PHYSICAL FEATURES.

Cache Creek, the only outlet of Clear Lake, is situated in Lake County, California, about 75 miles north of San Francisco. From the lake the creek flows eastward to the corner of Lake, Colusa, and Yolo counties, thence across Yolo County to the sink 8 miles northeast of Woodland.

Outlet of Clear Lake, Lake County.

Fourteen miles from the lake the main stream is joined by the North Fork, often called Cache Creek. This branch drains the country to the north and east of the lake, and adds very materially to the drainage area of the creek, but it is much smaller than the stream from the lake and should be considered a tributary.

The drainage area of the main creek and its branches has been estimated by the California State Engineering office as 1,192 square miles.

TOPOGRAPHY.

The country in Lake County tributary to Cache Creek is exceedingly mountainous and rugged. The peaks to the north rise to an elevation of 6,000 feet, and their slopes, as well as those of the lower ranges, may well be termed precipitous. On the northern slopes of the ranges

View of the falls on Cache Creek.

near the lake are magnificent belts of fir, white oak, and yellow pine. Elsewhere, however, the only evidence of vegetation is a dense growth of greasewood and chaparral. The interlaced branches of these shrubs make progress through them painfully difficult, but offer little resistance to escaping rain water.

From the Lake, Cache Creek flows through an open country for 5

miles, with a grade of 4.53 feet to the mile. It then follows Cache Creek Canyon for 25 miles. For the first 9 miles of its course through the canyon it has an average grade of 40.33 feet to the mile, varying from 20.41 feet to 137.94 feet. For the remaining distance the average slope is about 30 feet to the mile.

The mountains which form the walls of the canyon rise several hundred feet above the stream, and in many places the immediate banks of the creek stand as perpendicular cliffs 300 feet in height. The bed is generally rendered very rocky by outcropping sandstone and serpentine and the resulting boulders. At no place is there a basin which might be used effectively for storage purposes.

After leaving the canyon the creek enters Capay Valley, in Yolo County, through which it winds for a distance of 28 miles, with a grade of 9.5 feet to the mile. Capay Valley is 20 miles long and from one mile to three miles wide. From Capay Valley the creek enters the greater Sacramento Valley and flows, with a slope of 4 to 6 feet to the mile, to Tule Basin, bordering Sacramento River. There its natural channel ceases, and its waters enter a canal which connects the sink with Tule canal. The latter was built by the State of California in 1864 to drain Tule Basin. It empties into Big Lake in the extreme southeast corner of Yolo County, and from the lake its waters reach the Sacramento through a slough.

"Grigsby Riffle," on Cache Creek, near the junction of Seigler Creek.

Reservoir sites on North Fork of Cache Creek—The North Fork of Cache Creek rises in the mountains north of Clear Lake. Its principal tributaries are Bartlett, Wolf, and Long Valley creeks. Below Long Valley Creek there are no streams tributary to the North Fork. There are numerous canyons down which the storm waters rush after heavy rains, but none in which water can be found in summer. The North

Fork itself generally has no running water in its lower reaches after July.

Reservoir Site on North Fork—The only basins in the North Fork system which might be mentioned as reservoir sites are Twin Valleys, Little Indian Valley, and Long Valley.

The Twin Valleys are situated on a short branch of the North Fork a few miles north of Bartlett Springs. The upper valley is an ideal place for a storage basin; but as the entire catchment area above the valley is only 5 square miles, there would be very little water for storage purposes, and they cannot, therefore, be recommended as reservoir sites.

Long Valley is situated on Long Valley Creek, 2 miles from its mouth. It is 6 miles long, and has an average width of 1,000 feet, and a grade of 25 feet to the mile. Although it has a drainage area of about 30 square miles, the run-off during the drier years, when water is most needed, is stated, on excellent authority, to be very small, as might be expected from experience elsewhere in the same region. Moreover, the valley at its foot, the so-called Narrows, is 700 feet wide. Even should an ample supply be assured, the cost of a dam across the Narrows would be almost prohibitive.

LITTLE INDIAN VALLEY.

Little Indian Valley, the only basin on the North Fork to be recommended as a reservoir site, is 5 miles long, and averages from a half to three quarters of a mile in width. Almost half of the entire area is under cultivation, but the soil contains so much gravel that the grain crops are very light. A small portion of the middle of the valley and near the creek is irrigated for vegetables, a temporary earthen dam being thrown across the stream at a point where the rock outcrops.

A reconnaissance survey of the valley was made to determine its approximate storage capacity, contours being located at intervals of 25 feet, up to the 100-foot level. The following table shows the acreage of each of the four planes, and the storage capacity, in acre-feet, at the intermediate layers; also the total capacity for each contour. The area of the 125-foot contour is estimated to be 1,500 acres, which is considered a minimum figure, as the valley widens very appreciably at its upper end.

Storage Capacity of Little Indian Valley Reservoir Site.

Contour.	Area. Acres.	Capacity. Acre-feet.	Total capacity. Acre-feet.
25-foot	50	625	625
		4,625	5,250
50-foot	320		
		11,875	17,125
75-foot	630		
		20,500	37,625
100-foot	1,010		
		31,375	69,000
125-foot	1,500		
130-foot		7,500	76,500

Clear Lake—For a discussion of Clear Lake reservoir site see Water-Supply Paper No. 45.

STONY CREEK BASIN.

An investigation of Stony Creek basin was carried on in 1900 by the United States Geological Survey in co-operation with the California Water and Forest Association and the Willows Chamber of Commerce. The purpose of the surveys was to determine the location and capacity of reservoir sites, which could be utilized to store the flood waters of this stream so that the land in Glenn County above the Central Irrigation Canal, Sacramento Valley, could be irrigated. Stony Creek basin has peculiar topography. The main stream flows northerly and parallel with the Coast Range, and lies wholly in the sedimentary rock. It is fed by several tributaries which flow easterly from the granite crest of the Coast Range. These tributary streams have a very heavy grade from their source to near the point where they join the main stream and enter the sedimentary rock. At various points in the basin, a conglomerate of more or less hardness is upturned in line parallel with the axis of the main range and has resisted erosion to a very large extent. Wherever this ridge has been cross-cut by the various streams, dam and reservoir sites are found.

Reservoir sites of considerable merit were discovered and surveyed on Briscoe Creek, Little Stony Creek at East Park, subsequently developed by the United States Reclamation Service, and Stony Creek at Mill Site below the mouth of Grindstone Creek. Reservoir sites were also discovered on Grindstone and Salt creeks, but were not considered of sufficient capacity to justify a topographic survey. A site was found on the North Fork of Stony Creek, near the town of Newville, and a plane table survey was made up to the 60-foot contour. The capacity of this site is 25,400 acre-feet at this elevation. The area covered was 1,350 acres. The foundation and abutments at the dam site are not good. a portion of the land that would be flooded is very valuable, and the run-off from the drainage area tributary to the site was not considered sufficient to furnish 25,400 acre-feet annually. The possibility of increasing the water supply by diversion from Thomas Creek was investigated. It was ascertained that the cost of diverting this stream would be too great, but the plan was also not considered advisable because of the fact that a useful reservoir site exists on this stream below the proposed diversion point, which would be greatly damaged by the diversion.

East Park Site—This reservoir site is located on Little Stony Creek at the Lodoga. It has been developed by the United States Reclamation Service for the benefit of the Orland Project. The probable mean annual run-off of Little Stony Creek past the dam site is 98,000 acre-feet. The drainage area above the reservoir is 102 square miles in extent. The dam is of the concrete gravity type, erected to a maximum height of 139 feet. The length of the crest is 220 feet and the contents

equal 13,000 cubic yards. The area of the reservoir is 1,800 acres and the capacity, 45,000 acre-feet. The dam has a spillway length of 415 feet at an elevation of 85 feet above the stream bed. The cost of the reservoir is about $4.50 per acre-foot stored.

Briscoe Creek—This creek has a catchment area of 58 square miles of good mountain drainage. The crest of the drainage is a high mountain, locally known as Sheetiron Mountain, and inhabitants of this locality report that it lies in what may be termed a "rainy belt" having a width of about six miles and extending northeast from this mountain about 8 miles. Briscoe Creek, in section 30, township 20 north, range 6 west, Mt. Diablo Meridian, intersects a conglomerate bed in a narrow rocky gorge that is in places only 3 feet wide. The site was surveyed and found to have a capacity of 14,385 acre-feet with a dam 125 feet

A reservoir under construction above Volta, Cal.

high. The estimated annual discharge of the stream at the dam site is 55,000 acre-feet. A subsidiary dam at the divide, 1,700 feet north of the dam site, will also be necessary, with a maximum height of 30 feet. The conglomerate at the dam site is very hard. A sample taken weighed 143 pounds per cubic foot. Bedrock is at the surface in the canyon at the dam site, and the walls of the canyon are firm.

In the year 1900 the Geological Survey made a study of three types of dams that were believed to be suited to this site. It was considered that the best type of dam for this place will be a cyclopean concrete gravity dam with a concrete spillway at the subsidiary dam.

The estimate of cost is as follows:

Estimate for dam on Briscoe Creek of type No. 1, concrete dam with wasteway to the north.

Specifications.	Feet.
Length of dam on crest	360
Width of crest	12
Maximum height	125
Radius of crest	300
Elevation at base of dam	60
Elevation at outlet	90
Elevation at crest of spillway	180
Elevation at crest of dam	185
Front slope	¼ to 1
Back slope	5 to 100
Capacity of reservoir	14,385 acre-feet
Weight of conglomerate	143 pounds per cubic foot
Estimated total cost	$251,024 00
Cost per acre-foot stored	17 45

On account of increase in the cost of materials, labor, etc., it is probable that the cost of this dam at the present time would be 50 per cent greater than the foregoing figure.

Mill Site—At a point on the main creek in section 1, township 21 north, range 6 west, Mt. Diablo Meridian, locally known as the "Mill Site," the main stream intersects a conglomerate bed. The location is 1¾ miles above the Geological Survey gaging station and 7 miles northwest of Fruto. As it is near the Sacramento Valley, and has back of it over 330 square miles of drainage area, exclusive of Briscoe and Little Stony creeks, this site is relatively important. A dam at this point, 95 feet above the stream bed, would impound 43,700 acre-feet of water. The mean annual run-off for the nine years, 1901-09, is 590,000 acre-feet.

The depth to bed rock is assumed to be 35 feet. The wall rock is not good, and material for concrete would have to be transported 1,600 feet. Owing to these conditions, it was decided to estimate on a loose or rock-filled dam with ample spillway. The dam designed has a top length of 1,240 feet; upper slope 1 to 1¼; lower slope, 1½ to 1; the upper slope to be faced with an earth embankment built against it with a slope of 3 to 1, the width of the rock on the top to be 15 feet and the earth 5 feet, making the finished crest 20 feet wide. The spillway, calculated to carry 36,250 second-feet of water when flowing 8 feet deep over the sill, is 500 feet wide by 10 feet deep, and would be located to the east of the dam through a low saddle, and discharge several hundred feet below the dam.

Estimate of total cost of rock-fill dam at Mill Site, $670,010.00. Cost per acre-foot stored, $15.32.

These costs were estimated in 1900, and should probably be increased 50 per cent on account of increased cost of materials and labor.

Capacity of Mill Site Reservoir.

Contour. Feet.	Height of dam. Feet.	Area. Acres.	Capacity between contours. Acre-feet.	Total capacity. Acre-feet.
55	0	0	0	0
60	5	25.9	130	65
70	15	117.1	715	780
80	25	268.3	1,927	2,707
90	35	398.2	3,333	6,040
100	45	504.6	4,514	10,554
110	55	629.4	5,670	16,224
120	65	798.4	7,139	23,363
130	75	1,029.1	9,137	32,500
140	85	1,231.2	11,300	43,700

Elevation of outlet, 5 feet above bottom of reservoir.
Elevation of spillway, 85 feet above bottom of reservoir.
Capacity, 43,700—65=635 acre-feet.

This water could be used to irrigate the rich foothill lands on the west side of the Sacramento Valley between Orland and Willows.

The capacity of the Mill Site reservoir not being sufficient to impound all of the flow of Stony Creek, a further investigation was made in February, 1901, of the feasibility of diverting a portion of this water into Hambright and Eppinger creeks, small streams rising in the foothills and discharging into the Sacramento Valley. Certain reservoir sites exist on those streams too large to be filled from their drainage basins. The result of this investigation indicated that the cost of the diversion-canal line would be too heavy and the reservoir capacity not sufficient to justify the necessary expense incident to this construction.

GOOSE LAKE.

Goose Lake is situated in Lake County, Oregon, and Modoc County, California. The tributary drainage area is variously estimated at from 1,135 to 1,300 square miles. There are no topographic maps that fix the outline of the portion of the basin in Oregon. This basin is properly a part of the Sacramento River watershed, though no water has probably reached the Pit River from the lake since 1862. In the summer of 1904, Goose Lake covered approximately 186 square miles, or a little more than 119,000 acres.

In July, when the topographic survey was made of the outlet, the surface of the lake was one foot below the highest point in the outlet channel. The evaporation is ordinarily greater than the inflow. Taking the depth of evaporation to be three feet, the loss from the lake surface would be more than 300,000 acre-feet per annum. The above survey was made in order to determine the possibility of draining the lake entirely, or of reducing the area exposed to evaporation, and using the water thus saved for irrigating the lands along the Pit River. A preliminary hydrographic survey was also made to determine the depth of the lake. The soundings taken indicate that the bottom of the lake is comparatively level, and that the slopes near the shore are quite steep. The greatest depth found was 25 feet. The lake will have to be lowered 20 feet to reduce the area to approximately one half its present area.

The following table gives the approximate area and storage capacity of the lake for intervals of 5 feet:

Goose Lake.

(61 square miles in Oregon; 125 square miles in California; total, 186 square miles.)

	Area.		Capacity. Acre-feet.
	Sq. miles.	Acres.	
Lake full	186	=119,000	2,155,000
Lower 5 feet	171	=109,400	1,584,000
Lower 10 feet	161	=103,000	1,055,000
Lower 15 feet	142	= 90,900	568,250
Lower 20 feet	92	= 58,800	193,750
Lower 25 feet	29	= 18,600	Practically nothing

The following analysis of a sample of water from Goose Lake was made at the Agricultural Experiment Station of the University of California:

Analysis of water from lower end of Goose Lake, sample taken August 23, 1904, by S. G. Bennett.

	Grains per gallon.	Parts per 100,000.
Potassium sulphate (very small) } Sodium sulphate }	18.06	30.91
Sodium chloride (common salt)	7.02	12.02
Sodium carbonate (sal soda)	30.90	52.89
Calcium and magnesium carbonates, etc. (small) } Calcium sulphate (gypsum) trace } Silica, chiefly }	6.99	11.96
Organic matter, large, and chemically combined water	3.79	6.48
	66.76	114.26

"This result shows that the water is unfit for domestic and irrigation purposes."
(Signed) GEO. E. COLBY.

A large amount of the impurities in the water has resulted from concentration by evaporation, as there has been no outflow for about forty-two years. The water flowing annually into the lake is thought to be well adapted for irrigation purposes.

In February, 1905, the state legislatures of California and Oregon passed acts granting the Federal Government the right to drain certain interstate and navigable lakes, including Goose Lake, and relinquishing all rights to the swamp and overflow land thus covered. A bill was also passed by congress granting the U. S. Reclamation Service the right to change the water surface or drain said lakes.

JESS VALLEY RESERVOIR.

The dam site of the proposed Jess Valley reservoir is located on the South Fork of Pit River in section 10, township 39 north, range 14 east, Mt. Diablo base and meridian. The valley has been surveyed for 100 feet in elevation above the level of the stream bed at dam site, which is 100 feet above zero datum of survey and approximately 4,800 feet above sea level. The storage capacity at that elevation is 224,560 acre-feet. The capacity, divided by the area at the 100-foot contour, gives

an average depth of 66.56 feet, which indicates the steepness of the sides of the valley. The area of the watershed is 91 square miles. The drainage area includes Eagle Peak, which has an elevation of 9,934 feet. The principal part of the water supply is furnished by melting snow from Warner Mountains. The estimated run-off for the year 1904 was 71,300 acre-feet, which is equivalent to a depth of 14.70 inches over the entire watershed. The maximum discharge was 625 second-feet. The run-off in 1905 was approximately 39,100 acre-feet, or a depth of 7.41 inches. The probable average run-off for the five years 1904-1908 inclusive was 55,000 acre-feet. Thus the capacity of the reservoir is much greater than the supply.

Dam—Provisional plans and estimates have been made for a dam 60 feet high, the outlet level at 10 feet, and the spillway at 50 feet. The effective storage capacity is 81,346 acre-feet. There is practically no sand in this vicinity, so a rock-fill dam, with earth face, has been adopted as a type most suitable for the locality. On account of the scarcity of sand, the same type has been used in making estimates for West Valley, Warm Spring Valley, and Round Valley dams. The spillway would be formed by the excavation of the rock for the dam.

Specifications for rock-fill dam.

Length of dam at crest	805 feet
Width of crest	20 feet
Maximum height	60 feet
Survey elevation of outlet	110 feet
Survey elevation of spillway	150 feet
Capacity of outlet	275 second-feet
Estimated capacity of spillway	10,556 second-feet
(Spillway formed by excavation of rock for dam)	
Earth slope	3 to 1
Upper rock slope	1½ to 1
Lower rock slope	1½ to 1
Storage capacity	81,346 acre-feet
Weight of rock per cubic foot	168.8 pounds
Contents of rock-fill	35,170 cubic yards
Contents of earth-fill	21,360 cubic yards
Riprap on earth face	42,000 square feet
Contents of cut-off wall, concrete	1,500 cubic yards
Estimated cost of dam, spillway, cut-off wall, outlet works, right of way, engineering supervision and contractor's profits	$196,500 00

Assuming that 35,000 acre-feet can be furnished annually from the reservoir, the cost per acre-foot for the construction of the works will be $5.61. As this estimate was made in 1900, it will probably have to be increased about 50 per cent in order to allow for increased cost of material, labor, etc., at the present time.

WEST VALLEY RESERVOIR SITE.

This reservoir site is located on West Valley Creek, a tributary of the South Fork of Pit River. The area of the watershed tributary to West Valley is, approximately, 142 square miles. The estimated run-off for 1904 was 33,200 acre-feet, and for 1905, 16,200 acre-feet, and probably averaged about 25,000 acre-feet for the five years 1904-1908 inclusive. The valley has been surveyed for 100 feet in elevation above the level of the stream bed at the dam site, which is 100 feet above zero datum of survey and approximately 4,600 feet above sea level. The

storage capacity at that elevation is 94,579 acre-feet. The full capacity, divided by the area covered, gives an average depth of 51.12 feet. The sides of the valley are steep. The dam site is located in section 18, township 39 north, range 14 east, Mt. Diablo base and meridian.

Specifications for rock-fill dam.

Length of dam on crest	340 feet
Width of crest	20 feet
Maximum height	70 feet
Survey elevation of outlet	120 feet
Survey elevation of spillway	160 feet
Capacity of outlet	110 second-feet
Estimated capacity of spillway	10,556 second-feet
(Spillway formed by excavation of rock for dam)	
Upper earth slope	3 to 1
Upper rock slope	1¼ to 1
Lower rock slope	1½ to 1
Storage capacity	32,200 acre-feet
Weight of rock per cubic foot	169 pounds
Contents of rock-fill	39,315 cubic yards
Contents of earth-fill	23,515 cubic yards
Riprap on earth face	43,168 square feet
Contents of cut-off wall, concrete	1,450 cubic yards
Estimated cost of dam, spillway, cut-off wall, outlet works, right of way, contingencies, engineering, supervision and contractor's profits	$175,000 00

Assuming that 25,000 acre-feet can be furnished annually from the reservoir, the cost per acre-foot for the construction of the works will be $7.00. This estimate was made in 1904, and in order to keep pace with the increased cost of labor and materials, it will probably have to be increased about 50 per cent.

WARM SPRING VALLEY RESERVOIR.

The area of the watershed tributary to the Warm Springs Valley reservoir is 1,500 square miles, not including the Goose Lake drainage. The estimated run-off from this basin from January 1 to December 31, 1904, was 690,000 acre-feet, which is equivalent to a depth of 8.63 inches. The maximum discharge was 17,000 second-feet. The estimated run-off for 1905 was 156,000 acre-feet, which is equivalent to a depth of 1.95 inches. The mean flow for the five years 1904-1908, inclusive, averages about 423,000 acre-feet. The rainfall for 1904 was unusually heavy and that for 1905 unusually light. The valley has been surveyed 80 feet in elevation above the stream bed at the dam site in the lower half of the valley and 70 feet in the upper portion. The stream bed at dam site was assumed at 100 feet above zero datum of survey and is approximately 4,400 feet above sea level. The 180-foot contour takes in the town of Alturas, the county seat of Modoc County. The total capacity, divided by the area of the water surface at the 170-foot contour gives an average depth of 22.66 feet or 32.3 per cent of maximum depth. In making the plans of the dam, the outlet has been fixed at 20 feet and the spillway level at 60 feet above the stream bed at the dam. The effective capacity of the reservoir is 334,500 acre-feet. The basin may furnish this amount in years of average rainfall. This can only be determined by continuing the gaging records at Canby Bridge. The dam site is located in section 9, township 41 north, range 9 east, Mt. Diablo base and meridian.

Specifications for rock-fill dam.

Length of dam on crest	500	feet
Width of crest	20	feet
Maximum height	70	feet
Survey elevation of outlet	120	feet
Survey elevation of spillway	160	feet
Capacity of outlet	1,115	second-feet
Estimated capacity of spillway	21,110	second-feet
(Spillway formed by excavation of rock for dam.)		
Upper earth slope	3 to 1	
Upper rock slope	1¼ to 1	
Lower rock slope	1½ to 1	
Storage capacity	334,500	acre-feet
Weight of rock per cubic foot	170	pounds
Contents of rock-fill	78,669	cubic yards
Contents of earth-fill	49,646	cubic yards
Riprap on earth face	75,480	square feet
Contents of cut-off wall, concrete	2,500	cubic yards
Estimated cost of dam, spillway, cut-off wall, outlet works, right of way, engineering, supervision and contractor's profits		$670,300 00

Assuming that 334,500 acre-feet can be furnished annually from the reservoir, the cost per acre-foot for the construction of the works will be $2.00. This estimate was made in 1904, and in order to keep pace with the increased cost of labor, materials, etc., it will probably be necessary to increase the estimate by about 50 per cent.

ROUND VALLEY RESERVOIR ON ASH CREEK.

Ash Creek is a tributary of Pit River and enters this stream in Big Valley, near Bieber, California. The area of the watershed of Ash Creek, above the Round Valley reservoir, is 265 square miles. The run-off from this watershed was 160,700 acre-feet in 1904, 54,600 in 1905, and probably averaged about 107,000 for the five years from 1904 to 1908, inclusive. The valley has been surveyed for 100 feet in elevation above the level of the stream bed at the dam site, which is 100 feet above zero datum of survey and approximately 4,460 feet above sea level. At this elevation it would contain 184,700 acre-feet. This is a bowl-shaped basin. The average depth of the water would be 26 feet. The effective storage capacity of the reservoir as planned is 42,500 acre-feet. The height of the dam was fixed at 70 feet, on account of the softness of the rock in sight. It is believed that the basin will supply this amount in years of minimum rainfall. The dam site is located one half mile above Adin, Cal., in section 2, township 39 north, range 9 east, Mt. Diablo base and meridian.

Specifications for rock-fill dam.

Length of dam on crest	740	feet
Width of crest	20	feet
Maximum height	70	feet
Survey elevation of outlet	110	feet
Survey elevation of spillway	160	feet
Capacity of outlet	142	second-feet
Estimated capacity of spillway	7,460	second-feet
(Spillway formed by excavation of rock for dam.)		
Upper earth slope	3 to 1	
Upper rock slope	1¼ to 1	
Lower rock slope	1½ to 1	
Storage capacity	42,400	acre-feet
Contents of rock-fill	101,524	cubic yards
Contents of earth-fill	64,900	cubic yards
Riprap on earth face	104,680	square feet
Contents of cut-off wall, concrete	2,840	cubic yards
Estimated cost of dam, spillway, cut-off wall, outlet works, right of way, engineering, supervision, contingencies, and contractor's profits		$389,000 00

Dam near head of North Battle Creek, Northern California Power Company.

Cost per acre-foot for construction of works will be $9.16+, making the unit price for storage here greater than at any other of the Pit River reservoirs. This estimate was made in 1904, and in order to keep pace with the increased cost of materials, labor, etc., it will probably be necessary to increase the estimate by about 50 per cent.

BIG VALLEY RESERVOIR.

The area of the watershed tributary to the Big Valley Reservoir is approximately 2,950 square miles. If it is found possible to drain Goose Lake and divert the run-off from this basin into Pit River, the drainage area above Big Valley dam site will be about 4,200 square miles.

The mean run-off at Bieber for the five years 1904-1908, inclusive, was about 735,000 acre-feet. The area exposed to evaporation in the Big Valley reservoir, when the depth is 70 feet at the dam, is 83 square miles. Much of the time the reservoir would be only partially filled. The average area exposed to evaporation would probably not exceed 50 square miles.

This is the only dam thus far examined on Pit River where sand is found. The sand at this point is mixed with silt and will have to be washed.

Estimates of cost have been made for a dam 70 feet high above the bed of the stream with a heavy section to carry an overflow weir over part of the crest. It is believed that this will give the reservoir sufficient capacity to store all of the water furnished by the watershed.

In designing the outlet works, it has been assumed that 1,000,000 acre-feet could be supplied from the reservoir annually. It will be necessary to discharge this amount in five months, or 150 days, which is the usual length of the irrigation season. In order to do this, the outlet must have a capacity of 3,400 second-feet. The design includes

ten outlet gates 4 by 5 feet, which will discharge this amount under a 10-foot head. The dam site is located in section 27, township 37 north, range 7 east, Mt. Diablo base and meridian.

Specifications for overflow dam.

Survey elevation of base of dam	80 feet
Survey elevation of stream bed	100 feet
Survey elevation of outlet openings	120 feet
Survey elevation of weir crest	170 feet
Survey elevation of top of dam	180 feet
Height of dam	100 feet
Length on top	535 feet
Width on top	20 feet
Water slope	5 in 100
Lower slope	75 in 100
Capacity of reservoir	1,291,663 acre-feet
Estimate of cost of dam, outlet works, right of way, contingencies, engineering, supervision, and contractor's profits	$2,640,150 00

If the results of the continuation of the stream flow record should justify the first assumption that 1,000,000 acre-feet could be furnished annually from the reservoir, the cost per acre-foot for the construction of the works would be $2.64.

Assuming that 750,000 acre-feet can be furnished annually from the reservoir, the cost per acre-foot for the construction of the storage works would be $3.52. This estimate was made in 1904, and in order to keep pace with the increased cost of labor and materials, it will probably be necessary to increase the estimate by about 50 per cent.

Dam on North Battle Creek, near the head of creek, Northern California Power Co.

SACRAMENTO RIVER—IRON CANYON RESERVOIR.

The Iron Canyon reservoir site is located on the Sacramento River, 7 miles above Red Bluff, California. It was surveyed in September and October, 1903. The estimated effective capacity of this site is 226,900 acre-feet. The elevation of the top contour of the survey was 350 feet. The mean annual flow at this place is many times greater than the storage capacity.

The outlets must have sufficient capacity to discharge 226,900 acre-feet in 120 days in addition to passing 4,000 second-feet for navigation and 3,400 second-feet from Big Valley reservoir, if that should be constructed, or a total capacity of 8,350 second-feet. The gates designed have a capacity of 4,950 second-feet, under a 10-foot head. The cost of additional gates for passing Big Valley water was not included in the estimate.

In order to irrigate nearly 40,000 acres of red foothill and bench land near Red Bluff, which is thought to be particularly well adapted to fruit raising, it may be considered advisable to divert water from the reservoir at an elevation of 330 feet. If this should be done, the effective storage capacity of the reservoir would be 153,900 acre-feet. The advantage gained by making the diversion at this elevation would be a saving of the cost, and making possible the generation of about 16,000 horsepower of electrical energy from the water which it would be necessary to pass through the reservoir for navigation purposes, in addition to irrigating the land mentioned above. The intake tunnel would be about 10,000 feet southerly from the dam and 1,000 feet from spillway No. 2.

Dam—The dam site is located in section 27, township 28 north, range 3 west, Mt. Diablo base and meridian. A rubble concrete dam has been designed for this reservoir. There will be a spillway 1,200 feet in length on the left bank of the river at the dam, and one 600 feet in length located at a divide 9,000 feet southerly from the dam. The elevation of the sill of these spillways is 360 feet. The elevation of the top of the dam will be 370 feet. The combined capacity of the two weirs with 10 feet of water on the sills is 183,600 second-feet.

The difficulties to be contended with in the erection of this dam are the handling of the summer flow of the Sacramento River when putting in the foundations, and in preparing the works to withstand the flood discharge in the winter before the completion of the dam.

On either side of the low-water channel, which is a rock gorge of from 120 to 170 feet wide, there is a comparatively flat area of solid rock between the adjoining hills that form the flood channel. This area on the right bank is approximately 100 feet wide. A canal 100 feet wide with a depth of 10 feet and grade of 1 in 100 would carry 24,200 cubic feet per second.

Specifications for rubble concrete dam.

Elevation of base of dam above sea level	220 feet
Elevation of outlet	270 feet
Elevation of crest	370 feet
Elevation of spillway	360 feet
Maximum height of dam	150 feet
Weight of rock per cubic foot	166.6 pounds
Length of dam	740 feet
Length of spillway No. 1	1,200 feet
Length of spillway No. 2	600 feet
Width of crest	20 feet
Water slope	5 in 100
Lower slope	75 in 100
Capacity	226,300 acre-feet
Preliminary estimate of cost of dam, spillways, outlet works, right of way, engineering, supervision, contingencies, and contractor's profits	$1,855,000 00

The reservoir will hold 226,300 acre-feet of water, which makes the cost for building the works $8.20 per acre-foot stored. This estimate was made in 1904, and in order to keep pace with the cost of materials, labor, etc., it will be necessary to increase the estimate by about 50 per cent.

AMERICAN VALLEY RESERVOIR SITE.

A possible reservoir site exists at American Valley, Plumas County, in township 24 north, ranges 9 and 10 east, Mt. Diablo meridian. For the following reasons it seems doubtful if this site will ever be seriously considered in the near future. Quincy, the largest town and county seat of Plumas County, is located in this valley. The location of a transcontinental railway, the Western Pacific, passes through the dam site. An auxiliary dam 1,800 feet long would have to be constructed at a low divide one mile west of the main dam site.

A contour map of this valley was obtained from Mr. William Watson, C. E. The following table gives the capacity from 3,375-foot elevation to 3,450-foot elevation.

Contour.	Acres.	Acre-feet.	Total acre-feet.
3,375	633.4	3,167	3,167
3,400	2,364.1	14,987	15,154
3,425	3,613.7	29,889	45,043
3,450	4,588.8	41,012	86,055
		86,055	

A reconnaissance was made in the eastern part of American Valley, locally known as Thompson Valley, to see if it would be possible to utilize this as a storage reservoir. The width of the valley at the narrowest point is 1,300 feet. The capacity of this site with the greatest depth of water of 50 feet, would be 14,900 acre-feet.

SPANISH RANCH VALLEY.

A reconnaissance was made in September, 1905, of Meadow and Spanish Ranch valleys, located in township 24 north, range 8 east, Mt. Diablo meridian. The grade of the former is so steep that it could not be used for a storage basin. A reservoir of small capacity could be constructed at Spanish Ranch Valley.

The following table gives the capacity of this valley at 25-foot intervals from the 3,600- to 3,700-foot contour:

Capacity of Spanish Ranch Reservoir Site, Plumas County, California.

Contour.	Acres.	Acre-feet between contours.	Total acre-feet.
3,600	0		
		70	
3,625	23.5		70
		949	
3,650	166.3		1,019
		2,615	
3,675	356.8		3,634
		4,835	
3,700	610.2		8,469
		8,469	

Bedrock, which is serpentine, is exposed on the sides of the canyon and in the stream bed at the dam site.

BUCKS VALLEY RESERVOIR SITE.

A reservoir site is located on the west slope of the Sierra Nevada Mountains, Plumas County, in townships 23 and 24 north, range 7 east, Mt. Diablo meridian. Munford's Hill, which lies 5 miles northeasterly of this point, has a mean rainfall of 71.64 inches. The area of the watershed above the dam site is 28 square miles. The run-off from this area in years of mean rainfall would probably exceed 60,000 acre-feet. The principal part of the reservoir site is in private ownership. The dam site and the portion of the valley not in private ownership have been filed upon by private parties as placer mining claims.

The following table gives the capacity of the site:

Capacity of Bucks Valley Reservoir Site, Plumas County, California.

Contour.	Acres.	Acre-feet between contours.	Total acre-feet.
		2,072	
5,120	412.3		2,072
		13,687	
5,140	956.4		15,759
		16,200	
5,155.2 (Flood line)	1,175.2		31,959
		5,884	
5,160	1,276.4		37,843
		37,843	

In addition to its value as a storage basin for irrigation purposes, this reservoir site has considerable value in connection with future power development as Bucks Creek falls 3,000 feet in 8 miles.

GRIZZLY VALLEY RESERVOIR SITE.

A reconnaissance of Sierra Valley and vicinity was made in 1904 by S. G. Bennett. The Reclamation Service was requested to do this work by the inhabitants of this valley, who were anxious to have storage works and canals constructed for the purpose of increasing the irrigated area.

The mean elevation of Sierra Valley is probably 4,875 feet. It contains approximately 144,000 acres of land. There are said to be 25,000 acres under irrigation, the principal part of this being in the vicinity of Sierraville. There is very little alkali in the valley. The soil is a sandy loam. The price of unimproved sagebrush land is from $2.50 to $4.00 an acre. The point from which the people of Sierra Valley hoped to get the principal supply for reclaiming the valley was from the Little Truckee River. A ditch was built some years ago to divert water from this river to the valley, but on account of litigation it was never used. The ditch has a bottom width of 6 feet, and heads on Little Truckee River in township 19 north, range 15 east, Mt. Diablo meridian, near reservoir site No. 1 of the Truckee-Carson Project.

Three reservoir sites in the watershed of the Middle Fork of the Feather River were visited in making the above reconnaissance. These are located at Last Chance Valley, in Last Chance Creek, township 24 north, range 16 east, Mt. Diablo meridian; Graycroft's Neck, on the west side of the Sierra Valley in township 21 north, range 14 east, Mt. Diablo meridian; and Grizzly Valley, in townships 23 and 24 north, ranges 12 and 13 east, Mt. Diablo meridian. The site last mentioned was considered of sufficient value to justify further study and a topographic survey was made in October, 1905, by E. Johnson, Jr. The dam site is located in section 2, township 23 north, range 13 east, at an elevation of approximately 5,800 feet above sea level. The area below the 100-foot contour is 3,151 acres. The valley is used entirely for grazing purposes. The land is of rather poor quality and without improvements. Bedrock, which is granite, is exposed on the surface over the entire area of the dam site.

The following table gives the estimated capacity of the reservoir. Greatest depth of water is 98 feet.

Capacity of Grizzly Valley Reservoir Site.

Contour.	Acres.	Acre-feet.	Total acre-feet.
20	.6		
		10.5	
30	1.5		10.5
		108.5	
40	20.2		119.0
		376.0	
50	55.0		495.0
		1,036.5	
60	152.3		1,531.5
		3,950.5	
70	637.8		5,482.0
		10,209.0	
80	1,404.0		15,691.0
		18,697.0	
90	2,335.4		34,388.0
		27,432.0	
100	3,151.0		61,820.0
		61,820.0	

The drainage area tributary to the site is 45 square miles in extent. The run-off from its basin would probably not fill the reservoir to the 100-foot contour in years of low or mean rainfall.

An estimate has been made for a 90-foot concrete rubble dam. For additional safety, the structure would be curved upstream, with a radius of 300 feet at the upper face. The effective storage capacity of the site is approximately 34,300 acre-feet, with the outlet at the 30-foot elevation. The water stored at this point should be used for irrigating land in the Sierra Valley near Beckwith, California, and for a water supply for the town of Beckwith, though it could be used for irrigation in the Sacramento Valley. This land cannot be irrigated from any other source. Sierra Valley is a fertile valley, well adapted to the growing of alfalfa. The principal products of the farmers are oats, barley, wheat, beef, dairy products.

Specifications.

Elevation of base of dam	2	feet
Elevation of top of dam	90	feet
Elevation of outlet	30	feet
Elevation of datum of survey above sea level, approximately	5,800	feet
Width of dam on the crest	16	feet
Width of dam at the base	62½	feet
Length of dam on the crest	240	feet
Capacity of reservoir at 90-foot contour is	34,300	acre-feet
Capacity of outlet under a 10-foot head	116	second-feet
Capacity of outlet under a 60-foot head	284	second-feet
Area of land flooded at 90-foot contour	2,335	acres
Material, rubble masonry, 50 per cent of the mass to be large stones and 50 per cent concrete.		
Estimate of cost for dam, right of way, outlet works, engineering supervision, contingencies, and contractor's profits		$174,843 00

If 20,000 acre-feet are available annually, the cost of the storage works per acre-foot would be $8.74. On account of the increase in cost of materials and labor since the foregoing specifications were made, it is probable that the actual cost would be about 50 per cent greater than the above figures.

MOHAWK RESERVOIR SITE.

The grade of the lower portion of Mohawk Valley was considered to be too steep for the basin to be used as a reservoir. A reservoir site was surveyed by E. Johnson, Jr., in October, 1905, in the upper portion of this valley near Clio.

The following table gives the capacity of this reservoir from the 40-foot to the 100-foot contour:

Capacity of Mohawk Valley Reservoir Site.

Contour.	Acres.	Acre-feet.	Total Acre-feet.
40	1.1		
		69.5	
50	12.8		69.5
		367.0	
60	60.6		436.5
		1,222.5	
70	183.9		1,659.0
		2,392.0	
80	294.5		4,051.0
		3,536.5	
90	412.8		7,587.5
		5,039.0	
100	595.0		12,626.5
		12,626.5	

The results of the survey of this valley were disappointing. Its capacity was very much less than it was thought when the reconnaissance was made. On account of the location of the Sierra Valley Railroad and the town of New Mohawk, or Clio, within the area to be flooded by this reservoir, and because of the value of the other improvements in the valley, it is not considered that this site can be recommended for the location of a storage reservoir in the immediate future.

YUBA RIVER BASIN.

A reconnaissance was made in the watershed of the Yuba River to determine if there were any sites in this watershed suitable for storage reservoirs. No sites of value were discovered. A map of a reservoir site in township 17 north, range 6 east, Mt. Diablo meridian, known as Oregon House Valley, was obtained from the City Engineer of San Francisco. This site was surveyed in connection with the numerous investigations for a domestic water supply for San Francisco, and has a capacity of 90,823 acre-feet.

The following table gives the capacity of the reservoir site with greatest depth of water of 130 feet:

Capacity of Oregon House Valley Reservoir, North Yuba Project.

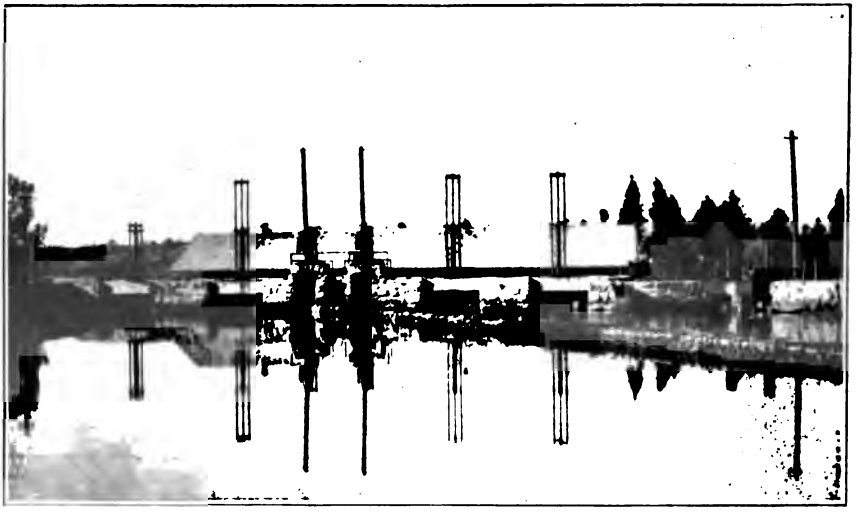
Contour.	Depth water. Feet.	Area in acres.	Capacity. Acre-feet.
1,480	0	0	0
1,500	20	18.2	182
1,510	30	85.5	700
1,520	40	164.3	1,950
1,530	50	296.8	4,255
1,540	60	460.7	8,042
1,550	70	665.6	13,674
1,570	90	1,097.5	31,305
1,590	110	1,491.5	57,195
1,610	130	1,871.3	90,823

The water supply would have to be obtained from the North Fork of the Yuba River by a diversion canal 9½ miles long, and a tunnel 5½ miles long. It is believed this site would be too expensive for utilization in connection with irrigation.

Twenty-two (22) reservoirs have been constructed in the watershed of the South Fork of the Yuba River. The water is used for mining and power purposes. The capacities of these reservoirs vary from 40 to 21,350 acre-feet. The most important of these were visited to determine if it were possible to increase their capacity by raising the dams. The total capacity of the twenty-two reservoirs is less than 87,000 acre-feet, and it is believed that the amount of storage that could be obtained by increasing the height of these dams would be insignificant. The run-off from the drainage area tributary to some of them is insufficient to fill them in average years. All of the reservoirs are in use except the English reservoir, at which point the dam failed several years ago.

AMERICAN RIVER BASIN.

The watershed of the American River is very precipitous and contains few basins that can be utilized as storage reservoirs. Those that exist are of comparatively small capacity.



View of Folsom Power House on the American River.

The Greenwood reservoir site, located in township 12 north, range 10 east, Mt. Diablo meridian, was surveyed in connection with the Lake Tahoe Project, San Francisco Water Supply Investigation. The water supply for this site was to have been obtained from Lake Tahoe. In order to tap the lake, a tunnel 6 miles long would have been necessary. The capacity of this site is approximately 66,000 acre-feet with

a 200-foot dam, and is probably the largest in the American River watershed.

The following table gives its capacity at intervals of 25 feet from 0 up to 200 feet:

Capacity of Greenwood Reservoir, American River.

Contour elevation. Feet.	Elevation of water surface.	Area in acres.	Capacity, acre-feet.
0	0	0	
50	40	43.20	864
75	65	157.94	3,378
100	90	272.64	8,761
125	115	416.39	17,374
150	140	560.12	29,580
175	165	720.55	45,588
200	190	908.52	65,962

RELATION OF STORAGE RESERVOIRS IN SACRAMENTO BASIN TO FLOOD FLOW.

Maps have been obtained of practically all the reservoir sites of economic value for irrigation purposes in the Sacramento basin. There may be other sites of relatively small capacity, which on account of the demand for irrigation water after much of the valley is irrigated and developed, will be of sufficient capacity and value to justify their survey and construction.

The storage basins described in the preceding pages, if constructed, would simplify the drainage problems of the lower Sacramento Valley. The Guenoc reservoir, if constructed, would entirely control the flow from 91 square miles of the watershed of Putah Creek. This area probably has a greater run-off than any equal area in the Sacramento basin.

The Monticello reservoir site is located 4 miles above the point where Putah Creek debouches upon the plain. It is believed that if both of these reservoirs were built the flood flow of Putah Creek could be so controlled that it would seldom exceed 10,000 second-feet.

The construction of Clear Lake and Indian Valley reservoirs would, in a measure, control the flood flow of Cache Creek, if the outlets were regulated with that object in view.

The flood wave of Stony Creek could be effectually controlled by the construction of Mill Site reservoir. Ordinarily reservoirs are allowed to fill with the first rains. The discharge records on Stony Creek show that the flow is many times more than the capacity of this reservoir. The reservoir could have been filled any year since the record began after the first of April. By increasing the outlet capacity and keeping the water low, this reservoir could be used as a regulator of the flood flow through the rainy season until the first of April.

If the Iron Canyon reservoir were built with a large outlet capacity, all ordinary flood waves would be controlled. If built according to

specifications given on page 62 it would still have the effect of retarding the passage of the flood crest on account of the large surface afforded, over which the water would be spread and stored before sufficient head was gained on the overflow weir to pass the flood flow.

The Big Valley reservoir of Pit River, if built, could store the entire winter flow from about 4,000 square miles of the watershed tributary to the Sacramento River.

The area of the watershed on the Feather River above reservoir sites which have been surveyed in this basin is 54 per cent of the total drainage area at Oroville, the point where it leaves the foothills. The Big Meadows, Butte Valley, Indian Valley, and Grizzly Valley reservoir sites have sufficient capacity to store, in years of mean rainfall, the entire discharge from 37 per cent of the Feather River watershed.

The Feather River is the largest tributary of the Sacramento River, and its maximum discharge exceeds 100,000 second-feet.

The area of the watershed tributary to the Iron Canyon, Putah Creek, Cache Creek, Stony Creek, Big Meadows, Indian, Butte and Grizzly Valley reservoir sites, is 48 per cent of the total area of the Sacramento basin.

From a study of the available stream flow data it is believed that the Cache Creek, Guenoc, Big Valley, Big Meadows, Butte, Grizzly and Indian Valley reservoir sites have sufficient capacity to hold back the flow from 21 per cent of the watershed of the Sacramento basin during the greatest storms.

Levees for flood protection—In spite of all precautions, crevasses sometimes occur. If a break should occur in the Sacramento levees, after the improvements proposed by the Board of Engineers have been carried out and after the flood basins have been reclaimed and settled, the loss of property might be enormous. There is a possibility of a break being attended with some loss of life. The property loss in one break might be greater than the entire first cost of the reservoirs which have been estimated upon in this report. Because of the intensity and amount of precipitation in the upper Sacramento River basin, its flood waves are great, but are of short duration. On this account the reservoirs will be especially useful in the reducing and retarding of the flood wave crests. It is believed that the additional expense of increasing the outlet capacity and making the reservoirs better adapted to serve the above purpose is justifiable and should be incurred. Inasmuch as levees have not proven universally successful in protecting lands adjacent to rivers from their flood flows, as may be cited in the case of the Mississippi River, it seems desirable to emphasize the important relation that storage bears to the reclamation of overflow lands in the Sacramento Valley.

It seems probable that a complete solution of this problem would require a system of storage reservoirs to control the flood discharge of the main river and its tributaries and thus remove the peaks of flood waves, and add a large safety factor to the stability of the levees.

It is also probable that a material portion of the first cost of such reservoirs might be saved in reducing the cost of levees and other flood-restraining works. It will be seen then how important it is that irrigation of the high valley lands and the reclamation of overflow lands be regarded as a coördinate work. The estimates and plans in this report must be considered as tentative only and likely to change when more detailed surveys are made and more stream flow data accumulated.

Effect of storage reservoirs on the flood of 1907—The rate of flow into the Sacramento Valley during the flood of 1907 largely exceeded the estimate previously used as a basis for computing the proper width of channel to safely carry the flood waters. The width of channel sufficient to carry that flow is so great that the question at once arises whether there is any other solution or partial solution of the problem. Is it not possible to protect the Sacramento Valley by levees against overflow without enormous expenditure for levee structures and a permanent loss of a strip of the best land in the valley, 1,500 to 2,500 feet in width along the river?

Very high flood stages last only a few days. If the rate of flow on these days could be reduced 20 per cent the necessary channel width might be reduced by the same percentage. The storage of a comparatively small proportion of the total flood volume will permit a material reduction in channel width through the whole length of the valley. At once the question is asked: Why cannot the reservoirs proposed for storing water for irrigation purposes be used so as to store the peak of floods and thus partly solve this problem?

Any acceptable scheme for improvement of flood conditions in this basin must include within its purview the interests of irrigation, navigation, and power. The use of a reservoir for flood and for industrial purposes conflicts to some extent. For industrial use it is necessary that the reservoir be full at the end of the rainy season; for flood protection it is necessary that it remain empty until the danger of a flood is past. As already stated, a flood may occur any time from January to the latter part of March. For effective flood protection, the reservoir should remain empty until the middle of March. Many reservoirs would have little value for industrial purposes unless the water were admitted to them early in the rainy season.

It will be instructive to determine the effect that storage in the proposed reservoirs would have had on the maximum rate of flow of some of the streams of the Sacramento basin during the four-day period, March 18 to 21, 1907. The following table gives the capacity of each proposed reservoir, the volume of flood flow for storage on each of these four days and the total.

Flow of streams for period March 18–21, 1907.

Stream and place.	Drainage sq. mi.	Date, March, 1907.					Per cent of flow.
		18th.	19th.	20th.	21st.	Mean 18-21.	
Sacramento—Red Bluff	9,300	118,000	165,000	196,000	132,000	153,000	30.7
Feather—Oroville	3,640	114,000	179,000	120,000	92,500	134,000	27.0
Yuba—Smartsville	1,220	85,000	100,000	60,000	27,000	68,000	13.6
Bear—Van Trent	263	11,400	25,800	13,500	5,620	14,100	2.8
American—Fair Oaks	1,910	70,000	105,000	86,000	72,500	83,400	16.8
Stony—Fruto	601	26,500	20,000	13,500	6,820	16,700	3.4
Cache—Yolo	1,230	13,700	19,200	12,700	7,240	13,400	2.7
Putah—Winters	805	20,200	25,400	8,900	4,850	14,800	3.0
Metered area	18,970	488,800	639,400	510,600	348,530	497,000	100
Unmetered Mountain and Foothills	3,880					*76,000	
Total	22,850					573,000	
Sacramento Valley	4,250					25,000	
Sacramento Basin	27,100					598,400	

*Run-off assumed as 50 per cent of precipitation March 17th to 20th.

It will be noted that some of these reservoirs would have been only partially filled by the flow of March 18th to 21st while others would have stored but a small percentage of the run-off that passed them. A study of this table will show that the four reservoirs in Stony Creek Basin would have stored the run-off from 457 square miles, or 76 per cent of the area above the gaging station, and would have reduced the maximum daily flow from 26,500 to 7,000 cubic feet per second. The two reservoirs in Cache Creek basin would have stored the flow from 609 square miles, or 50 per cent of the area above the gaging station, and would have reduced the maximum daily flow from 19,200 to 14,300 cubic feet per second. The two reservoirs in Putah Creek basin would have stored the flow from 751 square miles, or 92 per cent of the area above the gaging station, and would have reduced the maximum daily flow from 25,400 to 800 cubic feet per second.

The seven reservoirs in Feather River basin would have stored the flow from about 1,515 square miles, or 42 per cent of the area above the gaging station at Oroville, leaving 2,125 square miles uncontrolled. Of this uncontrolled area, 651 square miles are above Mohawk Valley reservoir, and 1,474 square miles are below the reservoirs and above the gaging station. This storage would have reduced the daily flow at Oroville as follows: from 144,000 to 114,000 cubic feet per second on March 18th; from 179,000 to 143,000 cubic feet per second on March 19th; from 120,000 to 90,000 cubic feet per second on March 20th; and from 92,500 to 69,500 cubic feet per second on March 21st.

Big Valley reservoir on Pit River would have stored the entire flow at that place and reduced the daily flow of the Sacramento River at Red Bluff about 25,000 cubic feet per second. The storage at Iron Canyon, together with that on Pit River, would have reduced the greatest daily flow of the Sacramento River at Red Bluff from 196,000 to 143,000 cubic feet per second.

The combined effect on the flow of the Sacramento of operating all of these reservoirs would have been to reduce the maximum daily flow at Red Bluff about 53,000 cubic feet per second; just below the mouth of Stony Creek, 63,000 cubic feet per second; and just below the mouth of Feather River, 92,000 second-feet.

It will be seen that as controllers of floods, some of these reservoirs do not present a very satisfactory showing on account of their location. Less than one fifth of their total capacity would have been in use on the four days of greatest flow and only 8 per cent of the combined capacity of the two largest (Big Valley and Big Meadows reservoirs) would have been in use on these days. If these reservoirs were at a lower altitude and had a larger per cent of the drainage basin above them, they would be more effective in flood control. Nevertheless, they would have very materially reduced the maximum rate of flow.

It will be instructive to indicate from the available records the probabilities of filling these reservoirs after the peak of floods has passed. A seven-year record on Stony Creek shows that the reservoirs

A view showing the gates controlling the flow of water from the Owens River into the Los Angeles Aqueduct.

in this basin will store the entire normal flow for February or March, but cannot be filled after March. A five-year record on Cache Creek shows that the reservoirs in this basin will store almost the entire normal flow for January and February combined, or for March alone, and can be filled ordinarily in April and May. From a four-year record on Putah Creek, it is found that the reservoirs in its basin will store almost the total normal flow for January and February, or for March, but that they cannot be filled after March. A six-year record on Feather River indicates that the reservoirs in its basin will reduce the normal flow about half in March or April, and that they can be

filled after April and May. The reservoirs on the Sacramento and Pit rivers will reduce the normal flow in March about one third. With all the reservoirs in operation, the indications are that the normal flow into the Sacramento Valley would be reduced about 44 per cent in March.

Open Canal of the Los Angeles Aqueduct some distance below the Owens River Valley.

MINIMUM RATES OF FLOW IN SACRAMENTO BASIN.

The years 1898, 1899, 1903, 1905 and 1908 have been years of comparatively small run-off in some or all parts of the Sacramento basin. The annual run-off for the years 1898 and 1899 are the smallest of record in the fifteen-year record at Red Bluff. The mean for these two years is only 70 per cent of the fifteen-year mean at this place.

The smallest monthly flow, however, at this place occurred in 1903 when the annual flow was 14 per cent greater than the fifteen-year mean.

The year 1908 was a very dry one in all parts of this basin, the flow being the smallest of record at several of the gaging stations.

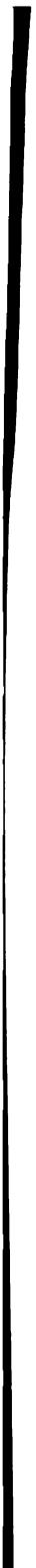
The following table gives the least mean rate of flow of record for fourteen consecutive days and for three consecutive months at the several gaging stations. Generally the three-month period includes the fourteen-day period, but not always:

Minimum rates of flow in Sacramento Basin.

Name and place.	Drainage. Sq. mi.	Date. Month.	Year.	Flow in sec.-feet. 3 months.	14 days.
Upper Sacramento River near Red Bluff	9,300	Sept.,	1903	4,250	3,980
McCloud River near Gregory	608	Sept.,	1903	1,313	1,280
Pit River near Bieber	2,950	Sept.,	1905	9	1
Feather River near Oroville	3,640	Oct.,	1902	1,343	1,170
Feather River near Big Bend	1,940	Aug.,	1908	1,062	980
Feather River below Prattville	506	Dec.,	1908	628	578
Feather, North Fork, above Prattville	245	Dec.,	1905	332	320
Hamilton Branch near Prattville	230	Dec.,	1905	178	168
Butt Creek in Butte Valley	73	Aug.,	1908	24	23
Indian Creek, Crescent Mills	740	Aug.,	1908	32	14
Yuba River near Smartsville	1,220	Oct.,	1908	400	320
Bear River near Sheridan	263	Nov.,	1905	23	15
American River near Fair Oaks	1,910	Sept.,	1908	*160	115
Stony Creek near Fruto	601	Aug.,	1902	4	2
Little Stony Creek near Lodega	102	Oct.,	1908	0	0
Cache Creek near Lower Lake	500	Oct.,	1908	11	6
Cache Creek near Yolo	1,230	Sept.,	1908	0	0
Putah Creek near Winter	805	Sept.,	1908	4	3.5
Cottonwood Creek near Ono	52	Aug.,	1908	19	3.2

*In 1905.

It is seen that the minimum flow of all these streams except the Upper Sacramento and McCloud rivers is small. Storage or auxiliary power is necessary to utilize much of the annual flow.



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